

**Seismic Hazard Characterization of the  
Savannah River Plant Site (SRP)**

**Jean Savy**

**November 1988**

The logo of the Lawrence Livermore National Laboratory is a large, stylized 'V' shape. The left vertical bar of the 'V' is composed of three horizontal layers: a white top layer, a dark grey middle layer, and a black bottom layer. The right vertical bar of the 'V' is also composed of three horizontal layers: a white top layer, a dark grey middle layer, and a black bottom layer. The bottom of the 'V' is a solid black curve. The text 'Lawrence Livermore National Laboratory' is written in a sans-serif font, slanted upwards from left to right, and positioned within the white space of the right vertical bar of the 'V'.

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A09	601

## **SRP SEISMIC HAZARD ANALYSIS**

- 1. Introduction**
  - 2. Methodology**
  - 3. Input Data**
  - 4. Seismic Hazard Estimates at the Savannah River Site.**
    - 4.1 Site description**
    - 4.2 Dominant zonal contributions**
    - 4.3 Hazard estimates with all seismicity and ground motion experts**
      - 4.3.1 Base case, contribution from earthquakes greater than  $m=5$ .**
      - 4.3.2 Contribution from earthquakes between magnitude 5 and 6.**
      - 4.3.3 Contribution from earthquakes greater than magnitude 6.**
      - 4.3.4 Contribution from earthquakes between magnitude 4 and 5.**
    - 4.4 Sensitivity Analysis**
      - 4.4.1 Results with four ground motion experts' input.**
      - 4.4.2 Effect of the local soil conditions.**
- Appendix A: References**
- Appendix B: Seismic zonation maps for each of the eleven seismicity experts (S-Experts) who provided input to develop data base used in the analysis of the Savannah River Site.**
- Appendix C: Seismic Hazard Characterization of 69 Nuclear Plant Sites East of the Rocy Mountains: Volumes 1 through 8. Bernreuter, D.L., Savy, J.B., Mensing, R.W. and Chen, J.C., NUREG/CR-5250, 1988.**



## 1. INTRODUCTION

In an effort to update the estimates at the Savannah Reprocessing Plant site (SRP), the Lawrence Livermore National Laboratory, through DOE/SR, was asked to provide such estimates by using its latest methodology and data banks.

On September 13, 1988 Elwyn Wingo, from Savannah River Laboratory requested that LLNL perform this calculation, which is funded by DOE/SR.

The scope of this study is to perform for the Savannah River site the same kind of calculation as performed for the Nuclear Regulatory Commission (NRC), using the same methods and data, as those used for all the active Nuclear Power Plant (NPP) sites located east of the Rocky Mountains.

The study for NRC was specifically designed to provide a set of tools with which the hazard at all the plant sites in the Eastern United States (EUS) could be estimated. However it must be noted that the very specific characteristics of each plant site are only accounted for in a generic fashion. For example, the local site corrections used eight different site categories rather than any site specific factors. In addition, the models of seismicity developed did not concentrate on any specific site locations, but were provided for the entire EUS. Similarly, the ground motion models used in the analysis did not concentrate on small regions, rather, they were separated in four different groups of models applicable to the four areas in the EUS, namely the North-East, the South east, North central, and South central EUS. A complete description of the methodology and of the data used here is presented in detail in Bernreuter et al., 1988 Volumes 1,6, and 7, provided in Appendix C of this letter report. The results provided by the NRC/LLNL methods with the present data banks are accurate enough that they can be used in screening techniques and for preliminary types of analyses. If a detailed site specific analysis were deemed necessary at a site, a careful revisiting and possibly updating of each of the links in the chain of analyses leading to the final data base would be appropriate.

The parameters of interest in the present study are:

1. The peak ground acceleration, considered to be at the site location in the free field.
2. The pseudo velocity response spectrum of the free field motion for 5% critical damping and at five frequencies (1Hz, 2.5Hz, 5.Hz, 10.0Hz, and 25Hz).

To provide some insights on the type of earthquakes which contribute the most to creating seismic hazard at the site, the results are given for all earthquakes greater than magnitude 5. (base case) and separately for the three following cases:

- contributing earthquakes are between magnitude 4 and 5 (case 2)
- contributing earthquakes are between magnitude 5 and 6 (case 3)
- contributing earthquakes are greater than magnitude 6 (case 4)

In Bernreuter et. al. (1988) it was found that the results were very sensitive to the choice ground motion model.

To provide an understanding in the behavior of the model with respect to the ground motion input, an additional set of results is given for the case when the Trifunac-Anderson ground motion attenuation model is removed from the data bank.

## **2. METHODOLOGY**

The hazard model used here is the now well accepted model developed by C.A. Cornell (1968).

The important aspects of the NRC/LLNL methodology consist of:

- using many experts opinions to include the knowledge uncertainty, as well as the physical uncertainty which is already included in the hazard model itself.
- propagating all uncertainties, in the seismicity modeling and ground motion modeling, through the use of a Monte Carlo simulation process.

The details of the methodology, including the hazard model and the process of elicitation of the experts' opinion, are given in Bernreuter et Al. 1985, Vol. 1 and Vol. 2 and Bernreuter et al. Vol 1, 6, and 7 (given in Appendix C). In particular Volume 7 details all the questionnaires used in the experts opinion elicitations.

## **3. INPUT DATA**

The input data used for this Savannah River Plant study, is exhaustively described in Bernreuter et. al. 1988 Vol. 1. The minimum magnitude of the earthquakes contributions to the hazard in the base case, is magnitude 5.0, and all five ground motion experts inputs are used.

## **4. SEISMIC HAZARD ESTIMATES AT THE SAVANNAH RIVER SITE**

### **4.1 Site Description**

The SRP site is located in South Carolina and is adjacent to the Savannah River. The coordinates of the site provided to LLNL and used in this analysis are:

- Latitude: 33.22° N (decimal)
- Longitude: 81.62° W (decimal)

"The SRP site is a deep soil site with depths to bedrock of 1,000 feet and greater. The upper soil layers are characterized as stiff clays and sandy clays; clayey sands, and dense silty and clayey sands. Shear wave velocities for the upper 200 feet are in the range of 1,000 to 1,200 ft/sec." This description of the site provided to LLNL, in the statement of work, lead to choosing category 5, per the LLNL Soil Site Classification (see Bernreuter et al., 1988, Vol. 1), as representative of the local site condition at the SRP site.

### **4.2 Dominant Zonal Contributions**

The dominant zonal contribution table (Table 1) is an attempt at identifying which of the seismic zones given by the seismicity experts (S-Experts) contribute the most to creating the seismic hazard at the SRP site. The percentages given in Table 1 are the ratios of the hazard provided by a zone, to the total hazard at the site, given only for the four highest contributing zones. (See Bernreuter et al. 1988, Vol 1, Appendix C).

**TABLE 1.0**  
**Seismic Hazard at the Savannah River DOE Site**  
**Most Important Zones Per S-Expert**  
**for Savannah**

**SITE SOIL CATEGORY: DEEP-SOIL**

S-XPT NUM.	HOST ZONE	ZONES CONTRIBUTING MOST SIGNIFICANTLY TO THE PGA BEHC AND % OF CONTRIBUTION AT LOW PGA (0.125G)					ZONES CONTRIBUTING MOST SIGNIFICANTLY TO THE PGA BEHC AND % OF CONTRIBUTION AT HIGH PGA (0.60G)			
		ZONE ID: % CONT.:	ZONE 2 49.	ZONE 1 33.	ZONE 3 9.	ZONE 9 8.	ZONE 1 76.	ZONE 2 22.	ZONE 3 2.	ZONE 9 1.
1	ZONE 1	ZONE ID: % CONT.:	ZONE 2 49.	ZONE 1 33.	ZONE 3 9.	ZONE 9 8.	ZONE 1 76.	ZONE 2 22.	ZONE 3 2.	ZONE 9 1.
2	ZONE 29	ZONE ID: % CONT.:	ZONE 30 76.	ZONE 29 20.	ZONE 18 4.	ZONE 27 0.	ZONE 30 81.	ZONE 29 18.	ZONE 18 0.	CZ 0.
3	ZONE 8	ZONE ID: % CONT.:	ZONE 9 87.	ZONE 8 10.	ZONE 7 3.	ZONE 5 0.	ZONE 9 83.	ZONE 8 17.	CZ 0.	ZONE 7 0.
4	ZONE 25	ZONE ID: % CONT.:	ZONE 10 91.	ZONE 9 6.	ZONE 4 3.	ZONE 25 0.	ZONE 10 98.	ZONE 9 2.	ZONE 25 0.	ZONE 4 0.
5	ZONE 10	ZONE ID: % CONT.:	ZONE 9 90.	ZONE 10 8.	ZONE 8 1.	ZONE 15 1.	ZONE 9 95.	ZONE 10 4.	ZONE 8 0.	ZONE 15 0.
6	ZONE 13	ZONE ID: % CONT.:	ZONE 13 99.	ZONE 14 1.	ZONE 11 0.	ZONE 18 0.	ZONE 13 100.	ZONE 14 0.	ZONE 11 0.	CZ 0.
7	ZONE 8	ZONE ID % CONT.:	ZONE 10 66.	ZONE 8 24.	ZONE 6 9.	ZONE 2 1.	ZONE 10 69.	ZONE 8 29.	ZONE 2 1.0.	ZONE 6 1.0.
10	ZONE 4	ZONE ID: % CONT.:	ZONE 15 48.	ZONE 4 42.	ZONE 28 9.	ZONE 19 1.	ZONE 4 82.	ZONE 15 16.	ZONE 19 1.	ZONE 28 0.
11	ZONE 8	ZONE ID: % CONT.:	ZONE 23 95.	ZONE 23A 4.	ZONE 24 0.	ZONE 22 0.	ZONE 23 100.	ZONE 23A 0.	ZONE 2 0.	ZONE 22 0.
12	ZONE 23	ZONE ID: % CONT.:	ZONE 23 49.	ZONE 23A 46.	ZONE 24 2.	ZONE 22 2.	ZONE 23 67.	ZONE 23A 32.	ZONE 24 0.	ZONE 22 0.
13	CZ 17	ZONE ID: % CONT.:	ZONE 9 70.	CZ 17 29.	ZONE 5 1.	ZONE 8 1.	ZONE 9 72.	CZ 17 26.	CZ 15 1.	ZONE 5 0.

However, one needs to be careful in interpreting the results presented in Table 1, since the calculation are made only with the best estimate hazard curves (BEHC) and not with the constant percentile hazard curves (CPHC).

The BEHC for a given S-Experts is obtained by setting each of the uncertain parameters equal to what each expert has defined as the most likely value of the parameter (zonation, seismicity parameters) and the most likely models of the ground motion experts (G-experts). Thus, the table of zonal contributions is only indicative of the relative contributions but it does not always represent accurately the relative contributions when all possible alternative, and all uncertainties are included.

The following is an interpretation of the zonal contributions of Table 1 for each of the 11 S-Experts used in the analyses. The zone numbers refer to the zones in the best estimate maps of the S-Experts which are given in appendix B.

- **S-Expert #1: (See fig. B1.1)**

The site is located in zone 1 which is a large zone encompassing the eastern seaboard, Florida, Louisiana, and part of Texas. Its upper source intensity cutoff ( $I_{\max}$ ) is 9.5. (approximately magnitude 6.5) The site is within 150 to 200 km of the Charleston region represented by zone 2 with an upper source intensity of 10, (approximately magnitude 6.75). Thus, the distant earthquakes of zone 2 are dominant at low PGA values, but at high PGA, the local earthquakes are the most important contributors. Zones 3 and 9 (New Madrid), contribute also small amounts to the hazard.

- **S-Expert #2: (See fig. B2.1)**

The site is located in zone 29 which is a kind of background seismicity zone for the Charleston area, and has an upper magnitude cutoff ( $M_{\max}$ ) of 6.5. The Charleston area (zone 30), approximately 150 km away from the site has  $M_{\max}$  of 7.5. As a result of this possibility of having much larger earthquakes in zone 30, the dominant zone is the Charleston area at all levels of PGA, followed by zone 29. The New Madrid seismicity area (zone 18), which is located several hundreds of kilometers away from the site, (400 to 600 km away) contributes a non-negligible amount (4%) at low PGA values.

- **S-Expert #3: (See fig. B3.1)**

The site is located in zone 8 with  $M_{\max} = 6.4$ , which is a background to the Charleston area (zone 9) with  $M_{\max} = 6.8$ . The extent of zone 9 comes relatively close to the site and thus dominates the hazard at all levels of PGA.

- **S-Expert #4: (See fig. B4.1)**



The site is located in a large area of low seismicity (zone 25), and low  $M_{\max} = 5.5$ . The Charleston area (zone 10) with its much higher  $M_{\max} = 6.8$  dominates the hazard entirely.

- **S-Expert #5: (See fig. B5.1)**

The site is located in a long North-South extending zone (zone 10) with relatively low  $I_{\max} = 8.0$  (approximately  $M_{\max} = 5.75$ ). By contrast, the Charleston area (zone 9) has a  $I_{\max} = 11$  (approx.  $M_{\max} = 7.25$ ) which, as a result, makes it the dominant contributor to the hazard.

- **S-Expert #6: (See fig. B6.1)**

The site is located in the regional zone 13 which encompasses the entire Charleston area and makes it almost the single contributor to the hazard. Note however that this is only in the best estimate case. For this expert, the other maps carry also a relatively high weight.

- **S-Expert #7: (See fig. B7.1)**

The site is located in zone 8, separated from the Charleston area where the seismicity is restrained to occurring in zone 10. Given the large difference in  $M_{\max}$  in these two zones ( $M_{\max} = 6.0$  in zone 8, and 7.3 in zone 10), the distant Charleston area (zone 10) is dominant. The distant New Madrid area (zone 6) and the overall complementary zone (zone 2), contribute also slightly to the hazard.

- **S-Expert #10: (See fig. B10.1)**

The site is located in a large eastern seaboard zone (zone 4) with diluted seismicity and  $M_{\max} = 6.0$ . By contrast, the Charleston area type of earthquakes are restricted to zone 15 with an  $M_{\max} = 7$ . As a result, both zones contribute substantially to the hazard. At low PGA values, they contribute almost equally and at high PGA the host zone dominates.

- **S-Expert #11: (See fig. B11.1)**

The site is located in a large eastern seaboard zone which includes all the seismicity associated with the Charleston area, making this zone the quasi single contributor to the hazard.

- **S-Expert #12: (See fig. B12.1)**

The site is located in zone 23 ( $M_{\max} = 6.0$ ) which is a kind of background for the Charleston area ( $M_{\max} = 6.9$ ). Both zones contribute substantially to the hazard with the local zones being slightly dominant.

- **S-Expert #13: (See fig. B13.1)**

The site is located in the large eastern seaboard type zone CZ17 ( $M_{\max} = 5.8$ ) which is a regional complementary zone and is not intended to

include the seismicity of the Charleston type which are restricted to occurring in zone 9 ( $M_{\max} = 6.7$ ). Both zones contribute substantially to the hazard with the distant Charleston area contributing, a factor of approximately two, more than the local earthquakes.

#### **4.3 Hazard Estimates with all Seismicity and Ground Motion Experts**

##### **4.3.1 Base case contribution from earthquakes greater than magnitude 5.0**

Figs. 1 through 11 show the results of the analysis for the Savannah site. When all the seismicity and ground motion experts' input are used and when the contribution of all earthquakes greater than magnitude 5 is accounted for.

##### **4.3.2 Contribution from earthquakes between magnitudes 5 and 6**

Figs. 12 through 22 show the results when only earthquakes between magnitudes 5 and 6 are accounted for in the analysis.

##### **4.3.3 Contribution from earthquakes greater than magnitude 6**

Figs. 23 through 33 show the results when only the earthquakes greater than magnitude 6.0 are accounted for in the analysis.

##### **4.3.4 Contribution from earthquakes between magnitude 4 and 5.0**

Figs. 34 through 44 show the results when only the earthquakes between magnitudes 4.0 and 5.0 are accounted for in the analysis.

#### **4.4 Sensitivity Analysis**

##### **4.4.1 Results with four ground motion experts' input**

The results presented in this section correspond to exactly the same cases treated in section 4.3. The only differences is that only the ground motion modeling from four of the five G-experts were used. In this case, the Trifunac-Anderson ground motion model was not considered.

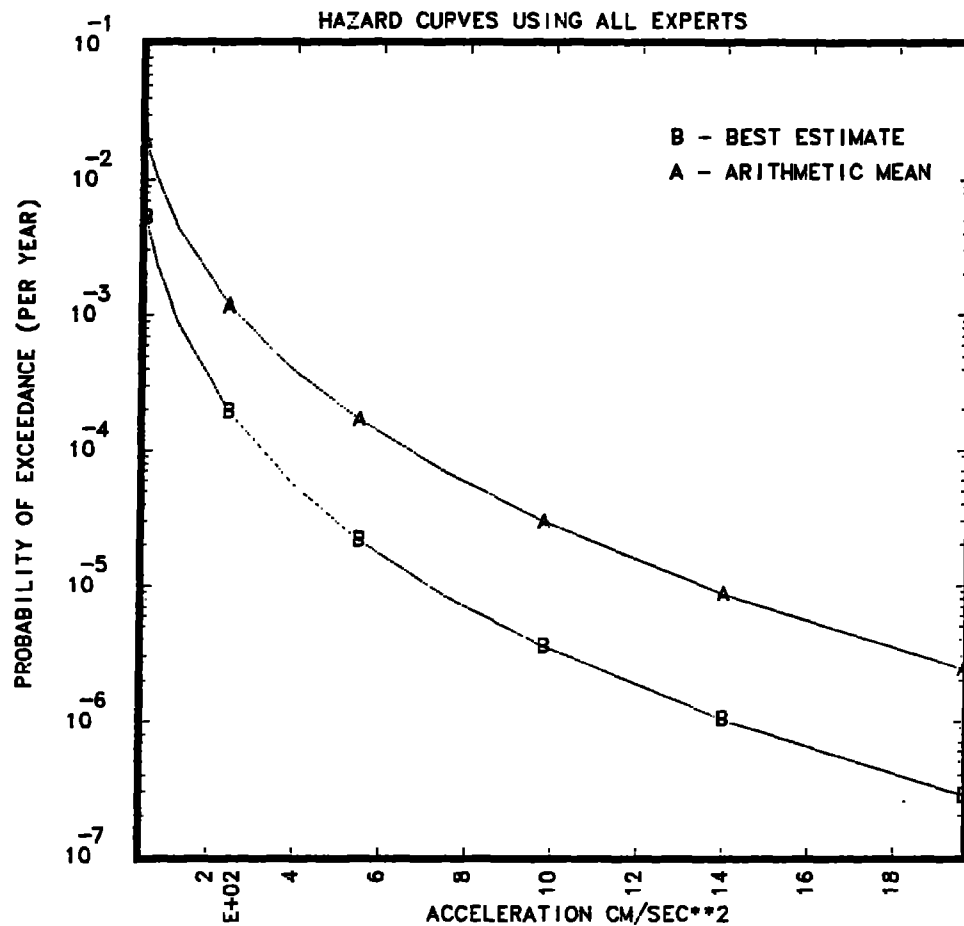
Figures 45 through 88 show the results of these analyses.

##### **4.4.2 Effect of the local soil conditions**

The base case calculations performed with the data presently available in the data bank applies to rock sites. For the sites with local soil conditions other than rock, a correction is performed in the manner described in Bernreuter, et.al., 1988 Vol.1.

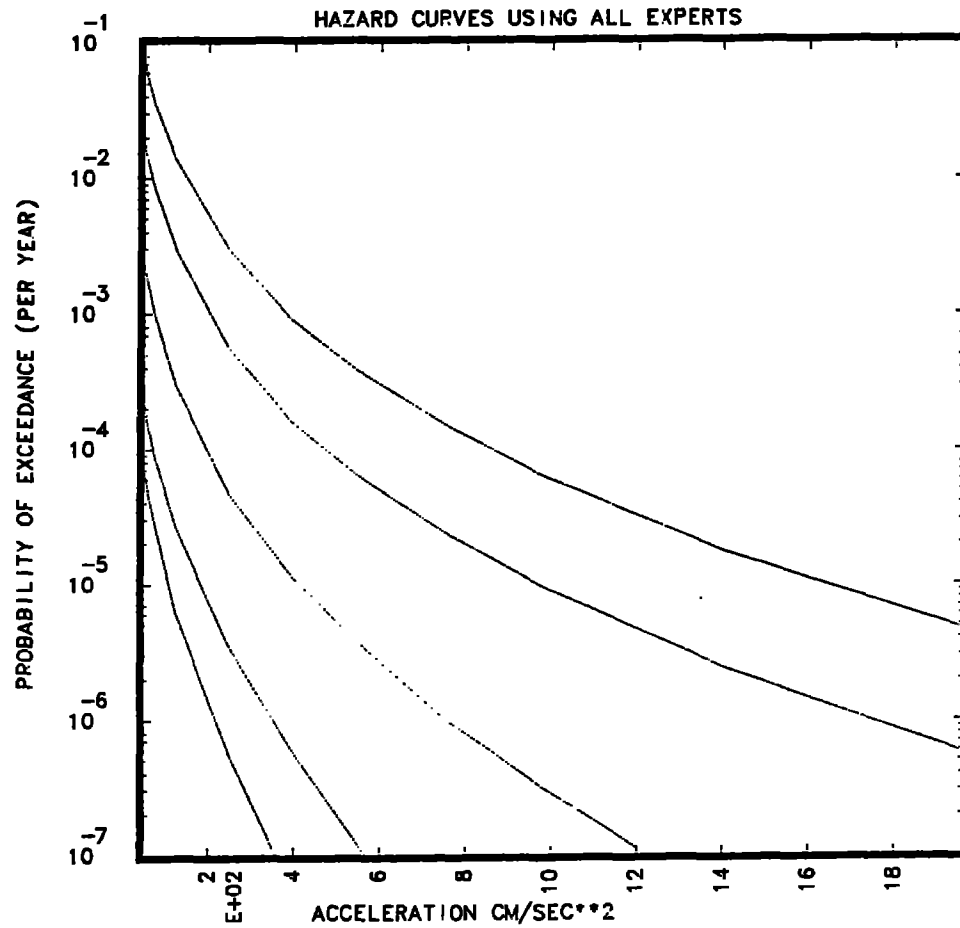
Typically, the deep soil correction for the Savannah river site has the effect of reducing the estimated hazard, as is shown in Fig. 2.2.4, of Bernreuter, et.al, 1988, Vol. 6 for PGA. For spectra, Fig. 2.2.6 shows that the deep soil correction tends to decrease the PSRV at high frequencies and raise it at low frequencies.

**Vol. 6 of Bernreuter et. al, 1988, analyses in detail the effects of the site correction applied in this study. In particular Sections 2.2 and 3.1 are of special interest to understand the results of the analysis for the Savannah River Site.**

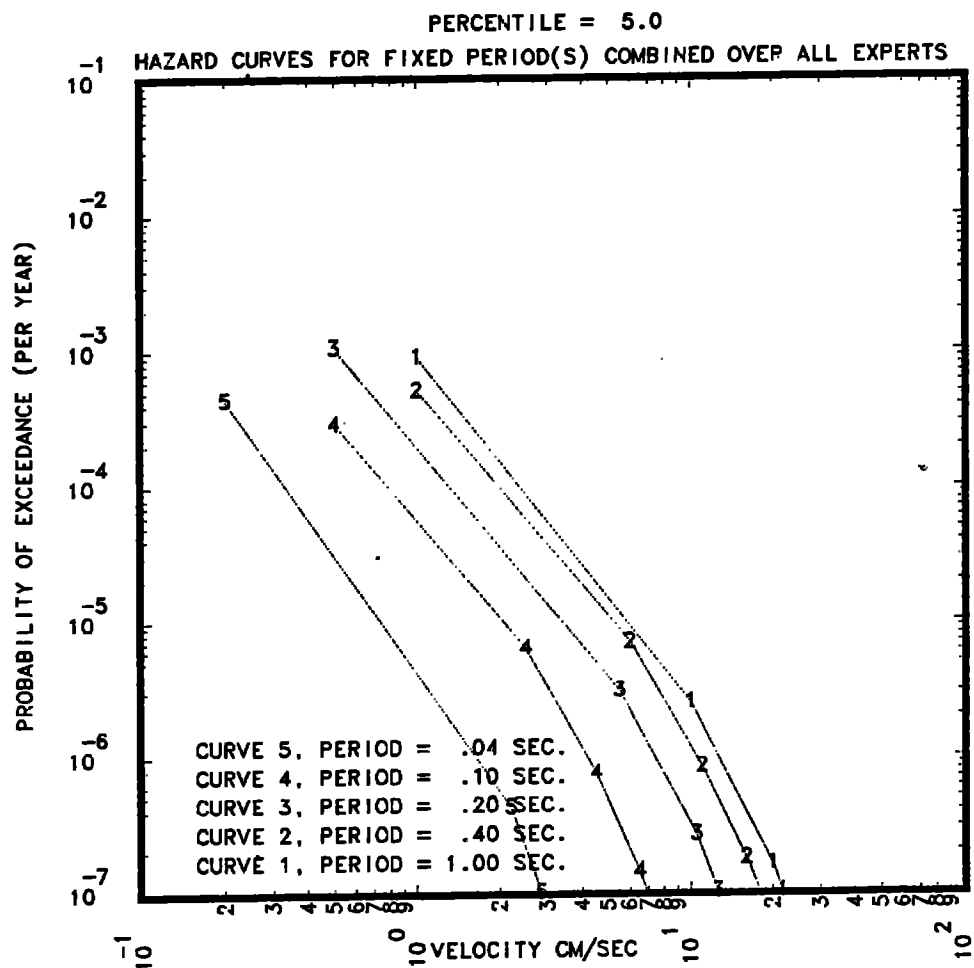


**Fig 1: Best estimate and arithmetic average hazard curves for the base case (Minimum contributing magnitude = 5.0) of the PGA for the Savannah River site.**

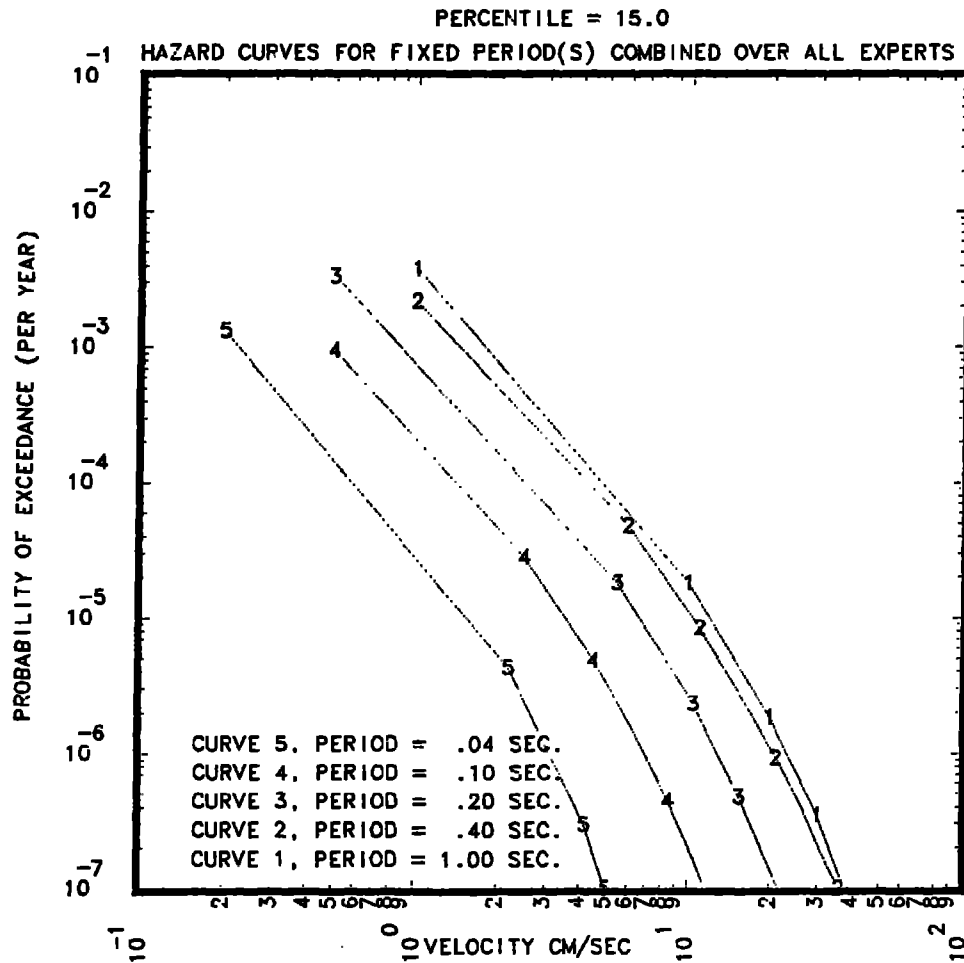
PERCENTILES = 5., 15., 50., 85., AND 95.



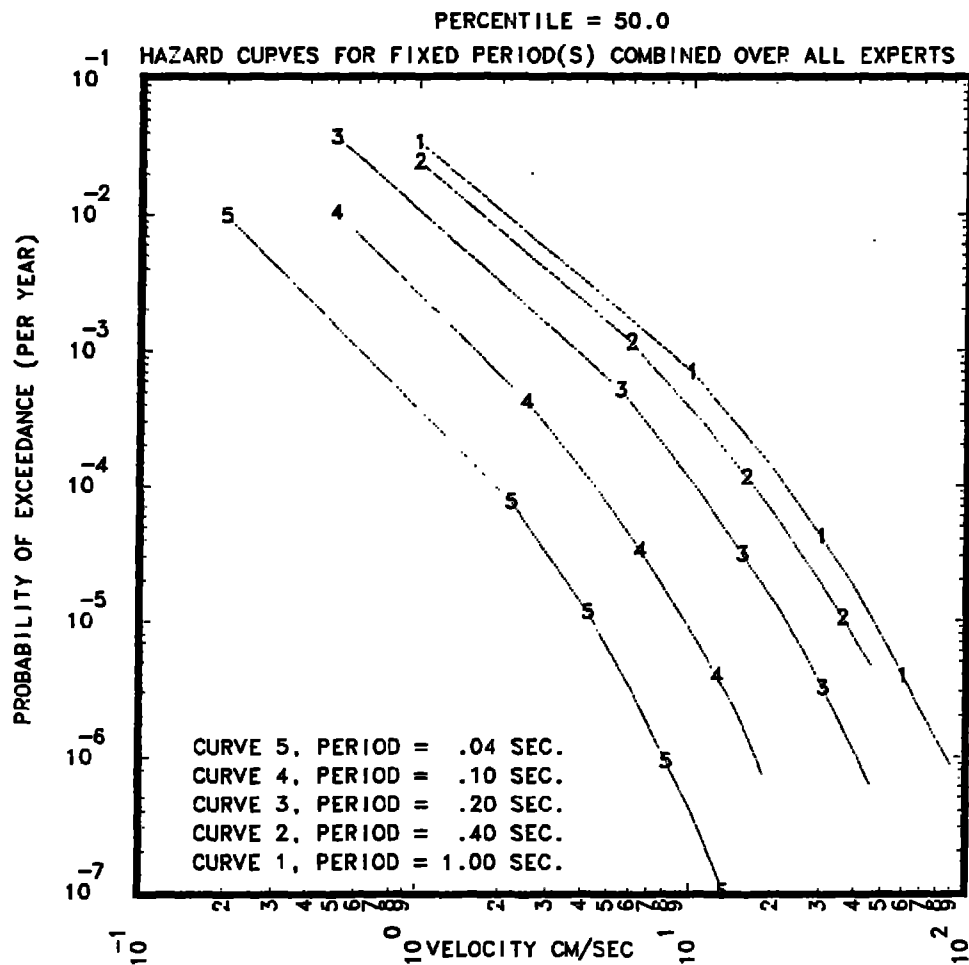
**Fig 2: 5, 15, 50, 85, and 95 percent constant percentile hazard curves for the base case (Minimum contributing magnitude = 5.0) of the PGA for the Savannah River site.**



**Fig 3: 5 percent constant percentile hazard curves for the base case (Minimum contributing magnitude = 5.0) of the PSRV at 5 frequencies for the Savannah River site.**

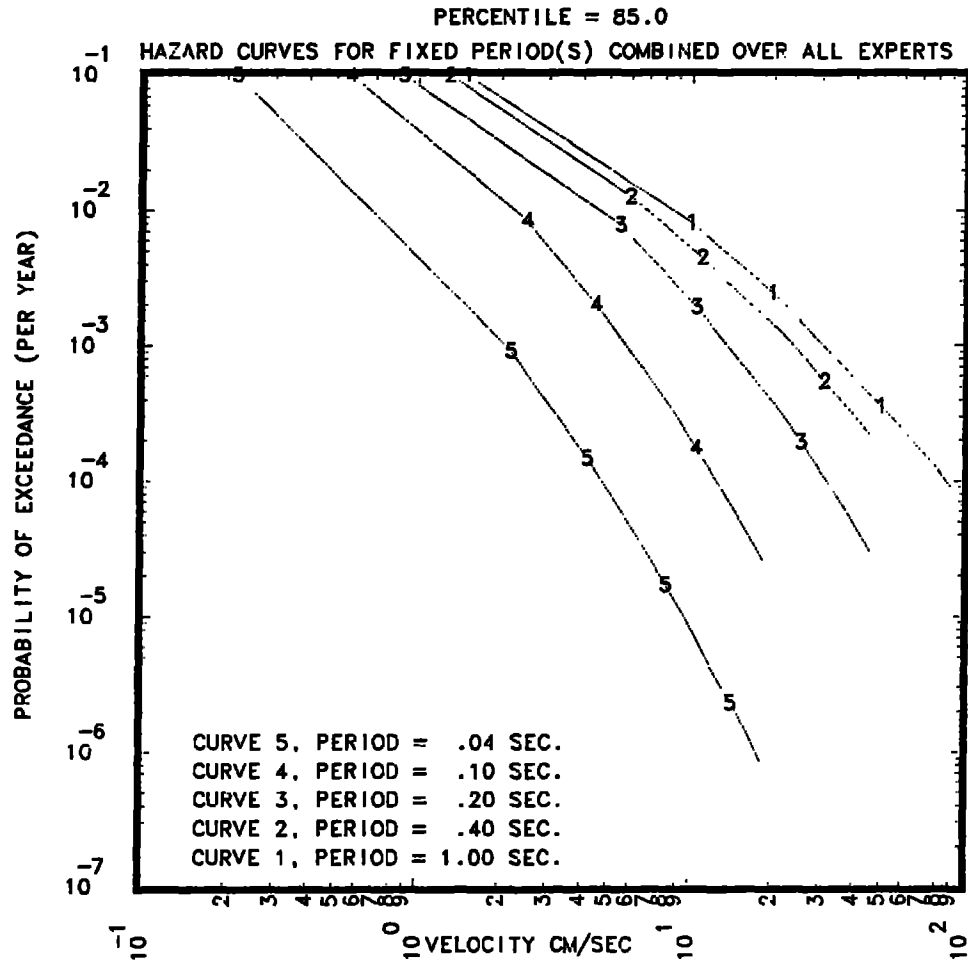


**Fig 4: 15 percent constant percentile hazard curves for the base case (Minimum contributing magnitude = 5.0) of the PSRV at 5 frequencies for the Savannah River site.**

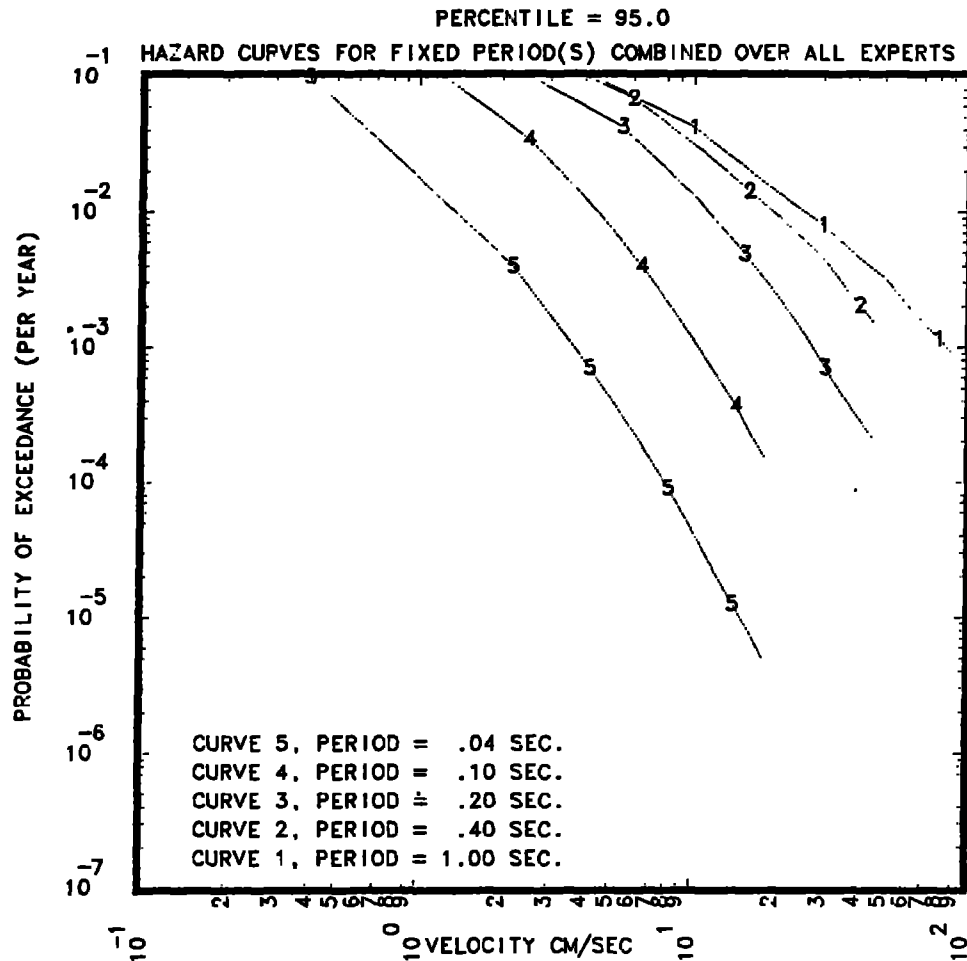


**Fig 5: 50 percent constant percentile hazard curves for the base case (Minimum contributing magnitude = 5.0) of the PSRV at 5 frequencies for the Savannah River site.**

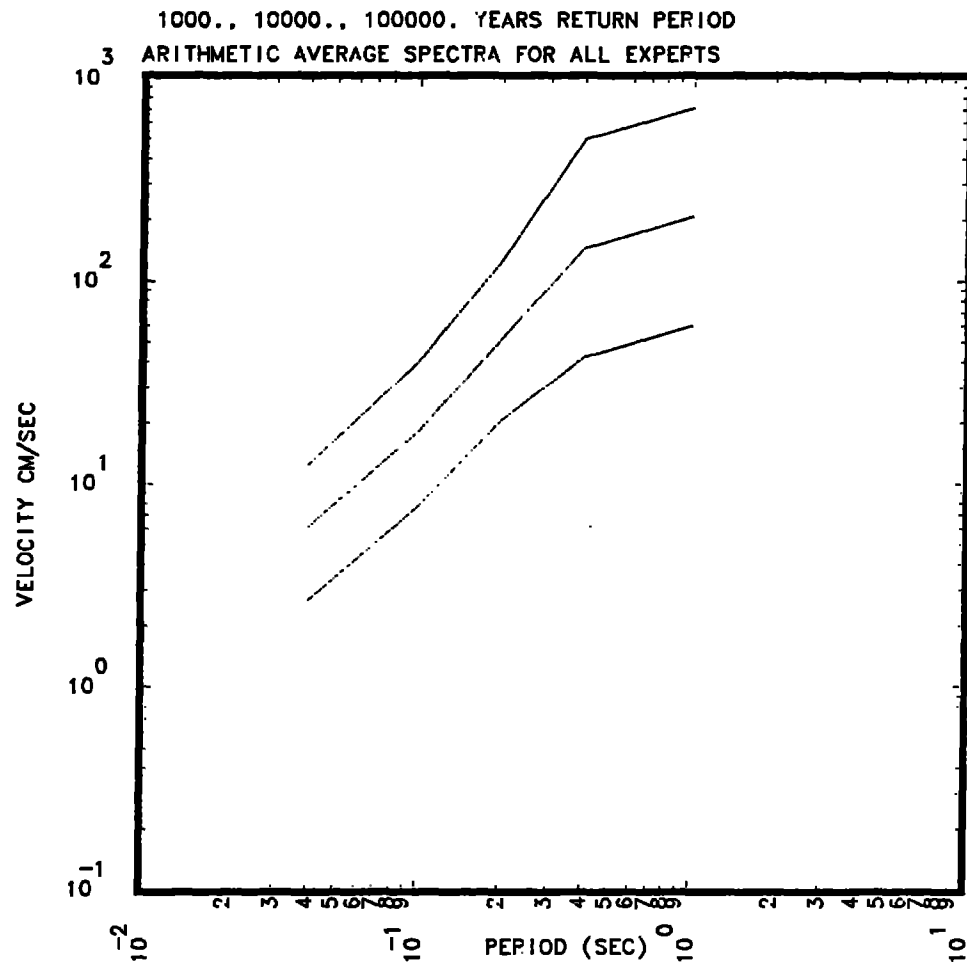




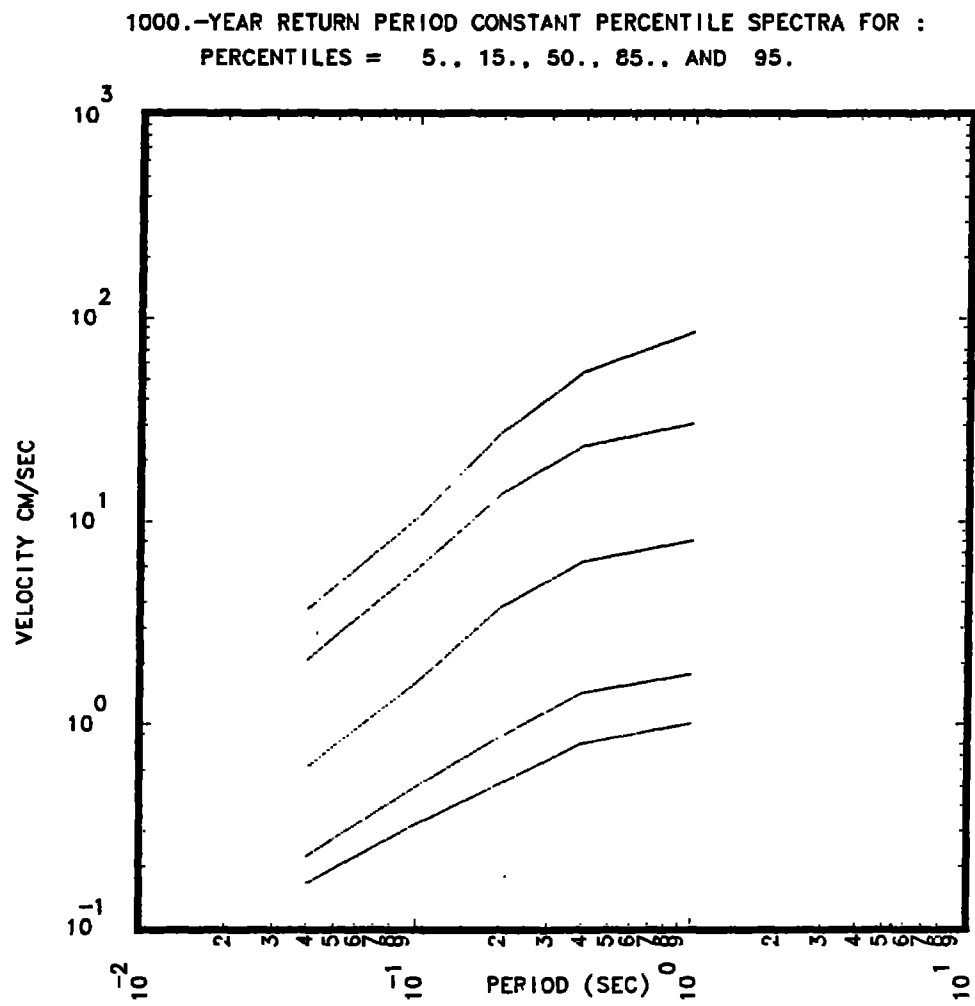
**Fig 6: 85 percent constant percentile hazard curves for the base case (Minimum contributing magnitude = 5.0) of the PSRV at 5 frequencies for the Savannah River site.**



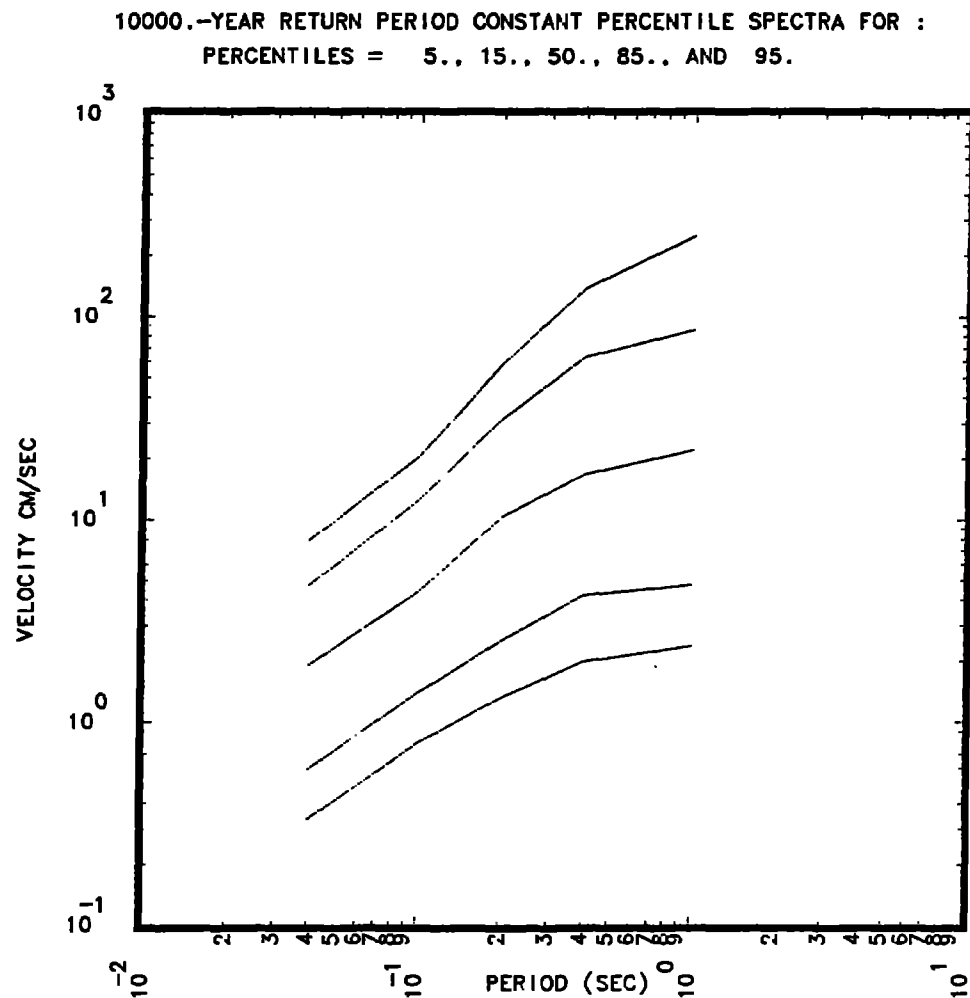
**Fig 7: 95 percent constant percentile hazard curves for the base case (Minimum contributing magnitude = 5.0) of the PSRV at 5 frequencies for the Savannah River site.**



**Fig 8:** Arithmetic average Uniform Hazard Spectra for three return periods for the base case (Minimum contributing magnitude = 5.0) for the Savannah River site.

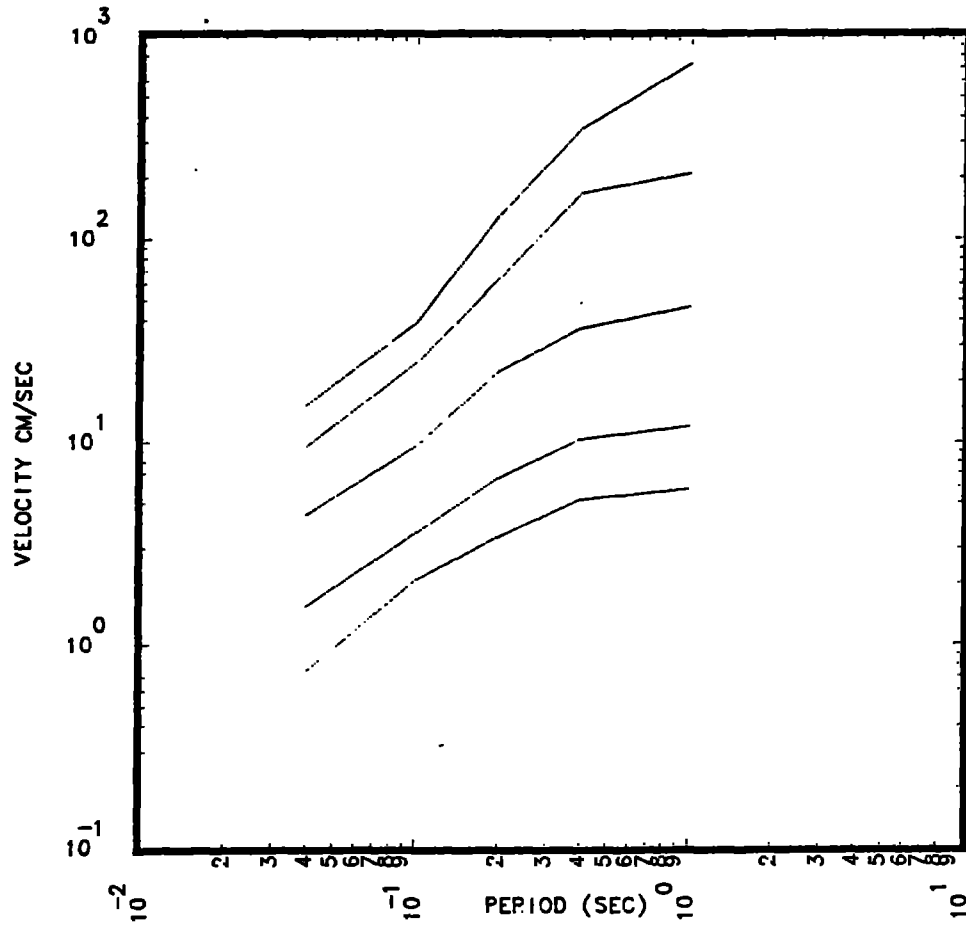


**Fig 9: 5, 15, 50, 85 and 95 percent constant percentile 1000 year return period Uniform Hazard Spectra for the base case (Minimum contributing magnitude = 5.0) for the Savannah River Site.**

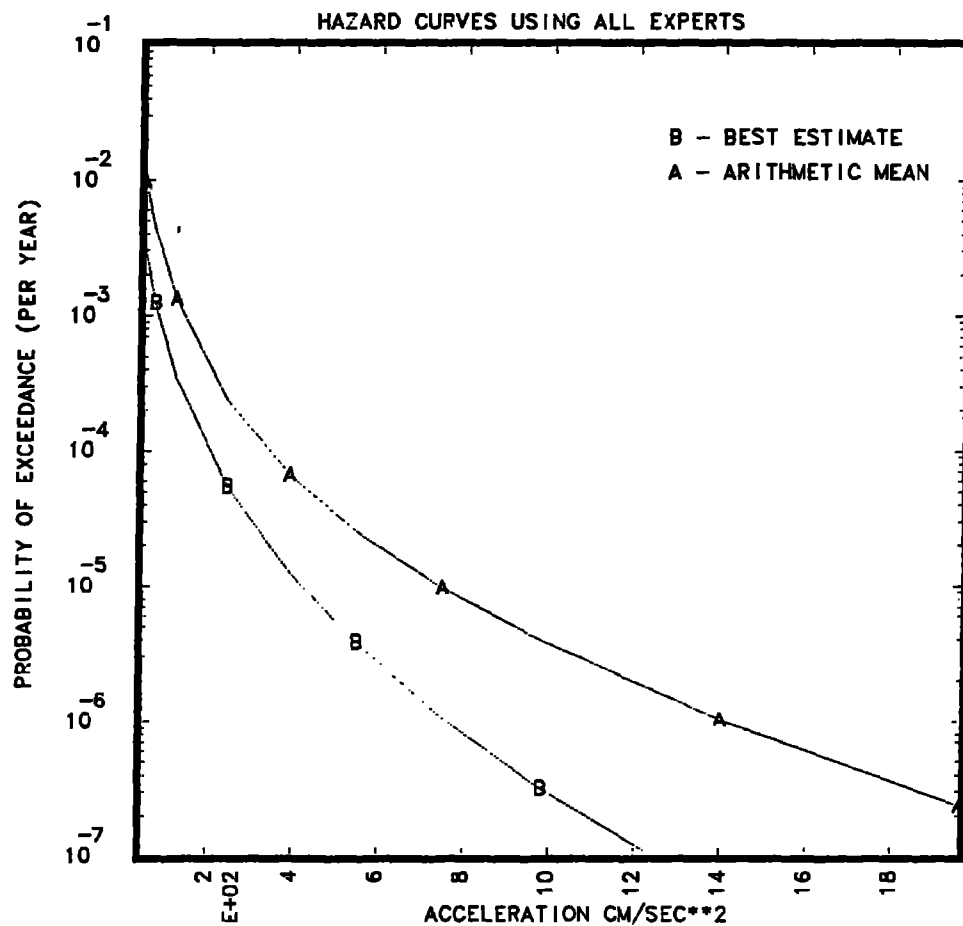


**Fig 10: 5, 15, 50, 85 and 95 percent constant percentile 10,000 year return period Uniform Hazard Spectra for the base case (Minimum contributing magnitude = 5.0) for the Savannah River Site.**

100000.-YEAR RETURN PERIOD CONSTANT PERCENTILE SPECTRA FOR :  
 PERCENTILES = 5., 15., 50., 85., AND 95.

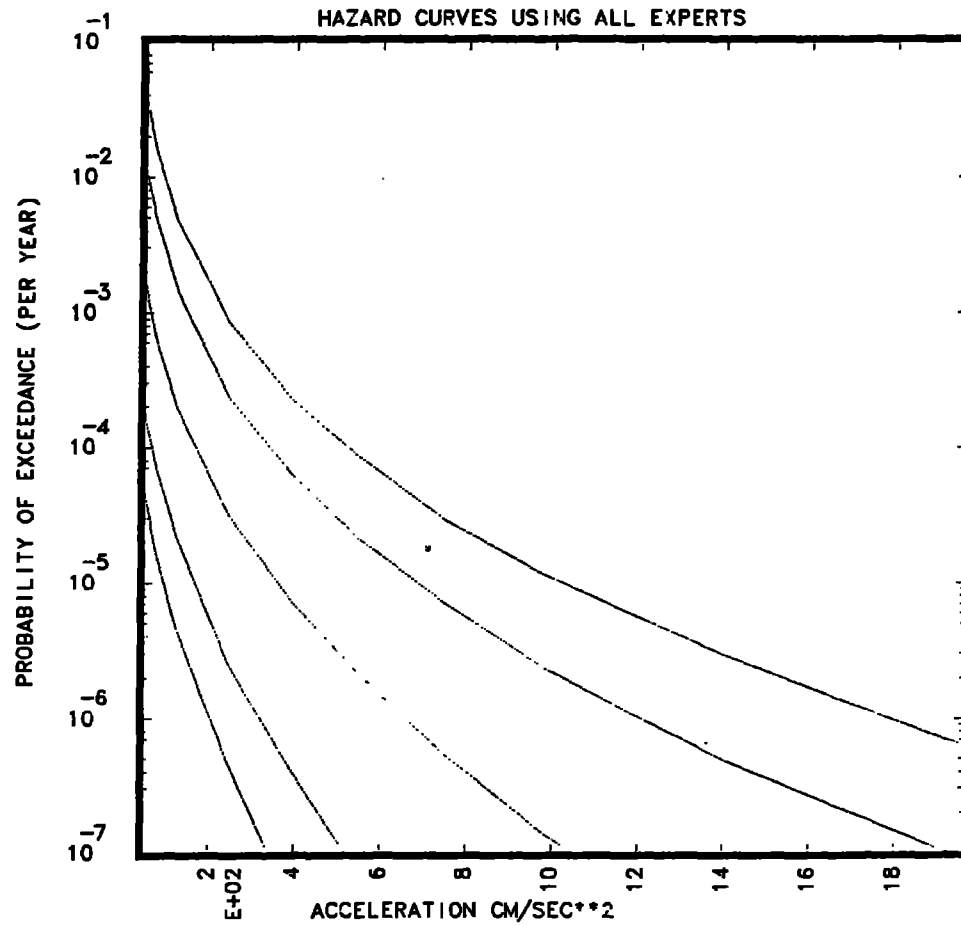


**Fig 11: 5, 15, 50, 85 and 95 percent constant percentile 100,000 year return period Uniform Hazard Spectra for the base case (Minimum contributing magnitude = 5.0) for the Savannah River Site.**



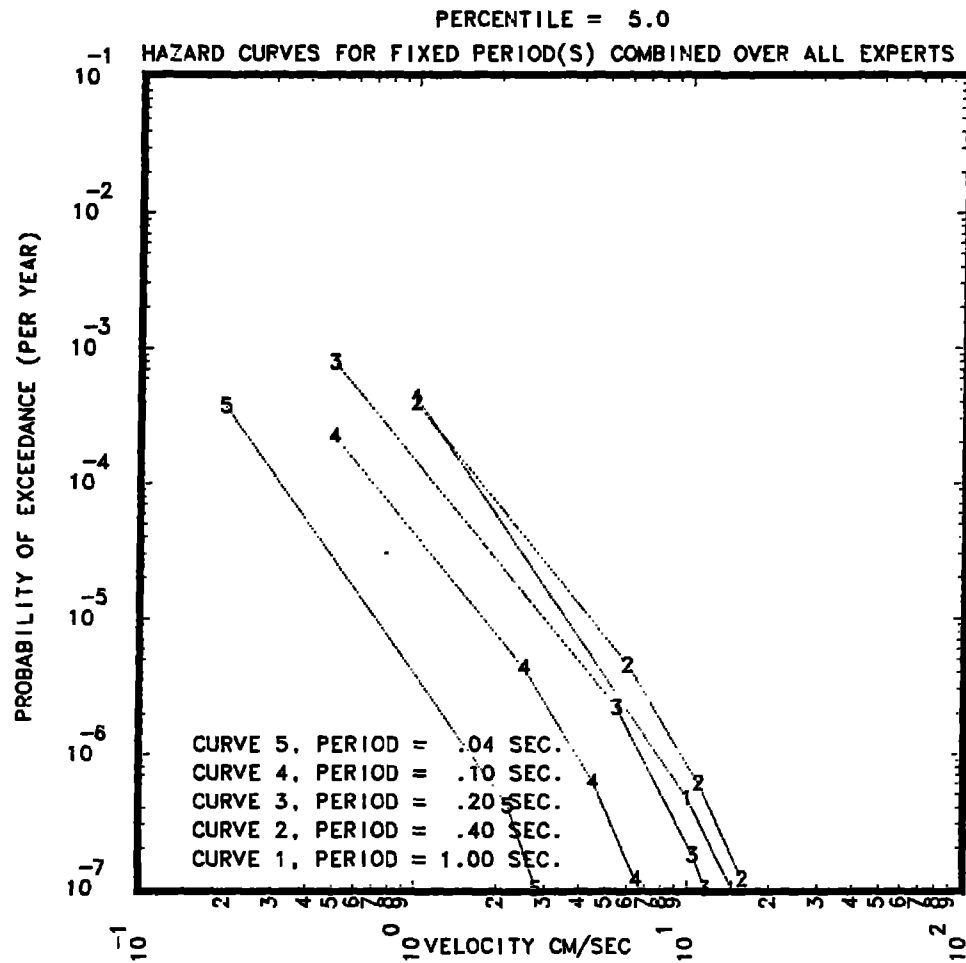
**Fig 12: Best estimate and arithmetic average hazard curves for the Case 2 (only earthquakes with magnitudes between 5 and 6 contribute to the hazard) of the PGA for the Savannah River site.**

PERCENTILES = 5., 15., 50., 85., AND 95.

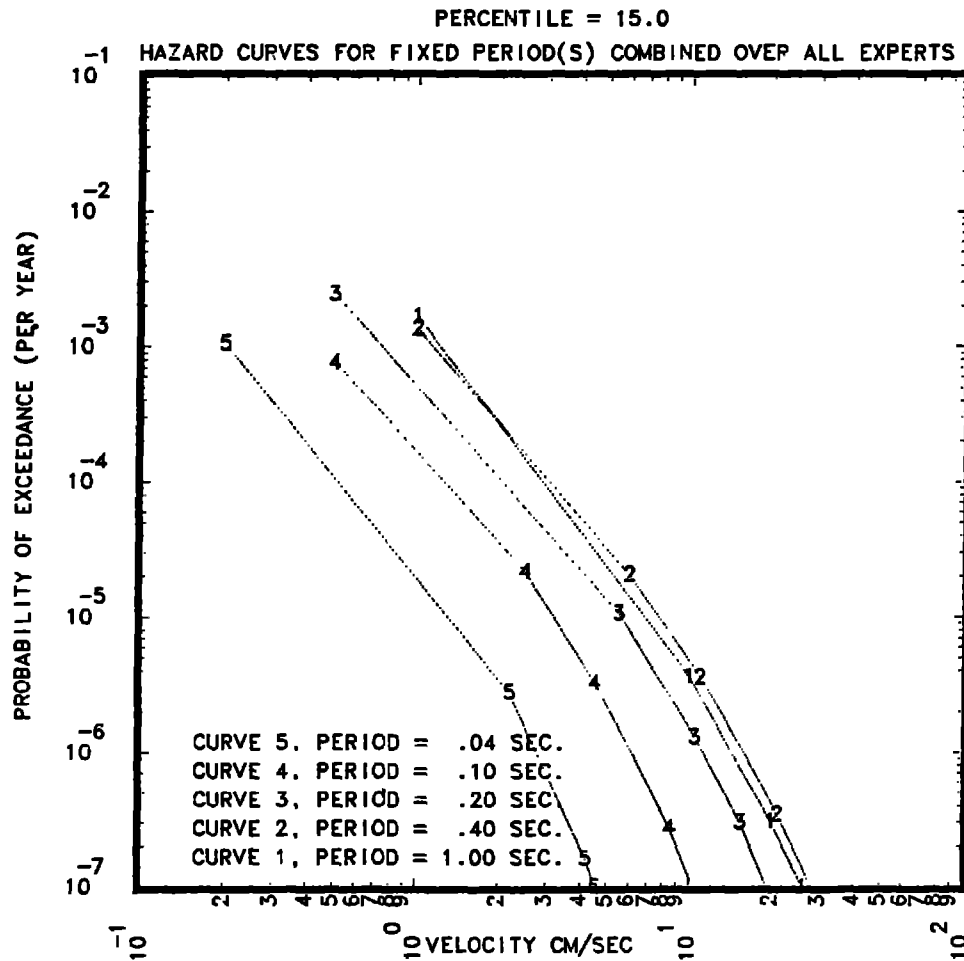


**Fig 13: 5, 15, 50, 85, and 95 percent constant percentile hazard curves for the Case 2 (only earthquakes with magnitudes between 5 and 6 contribute to the hazard) of the PGA for the Savannah River site.**

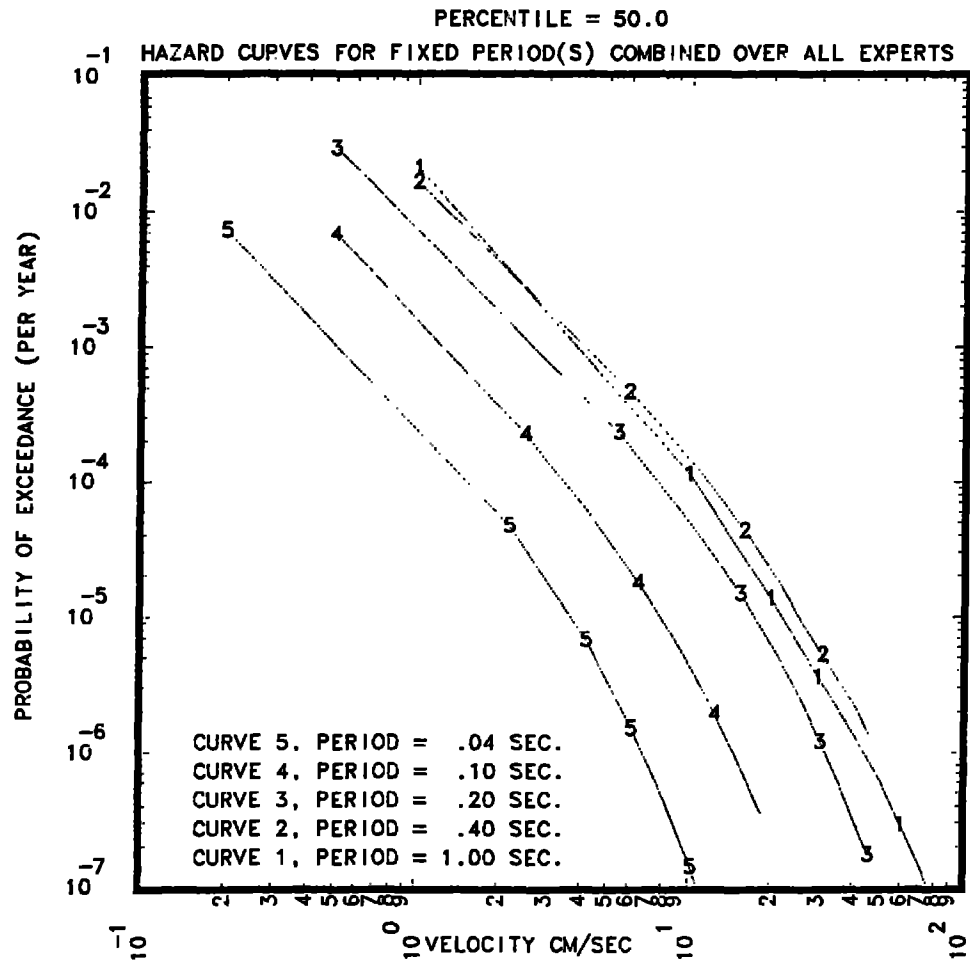




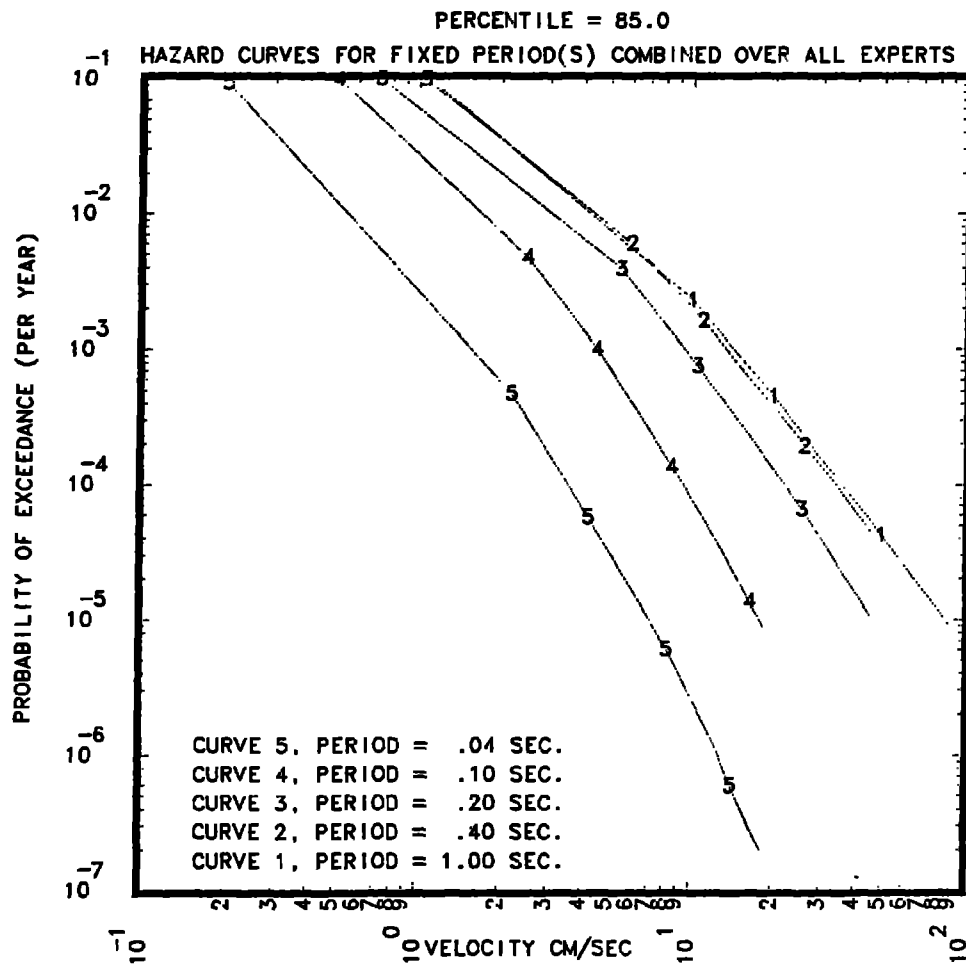
**Fig 14: 5 percent constant percentile hazard curves for the Case 2 (only earthquakes with magnitudes between 5 and 6 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site.**



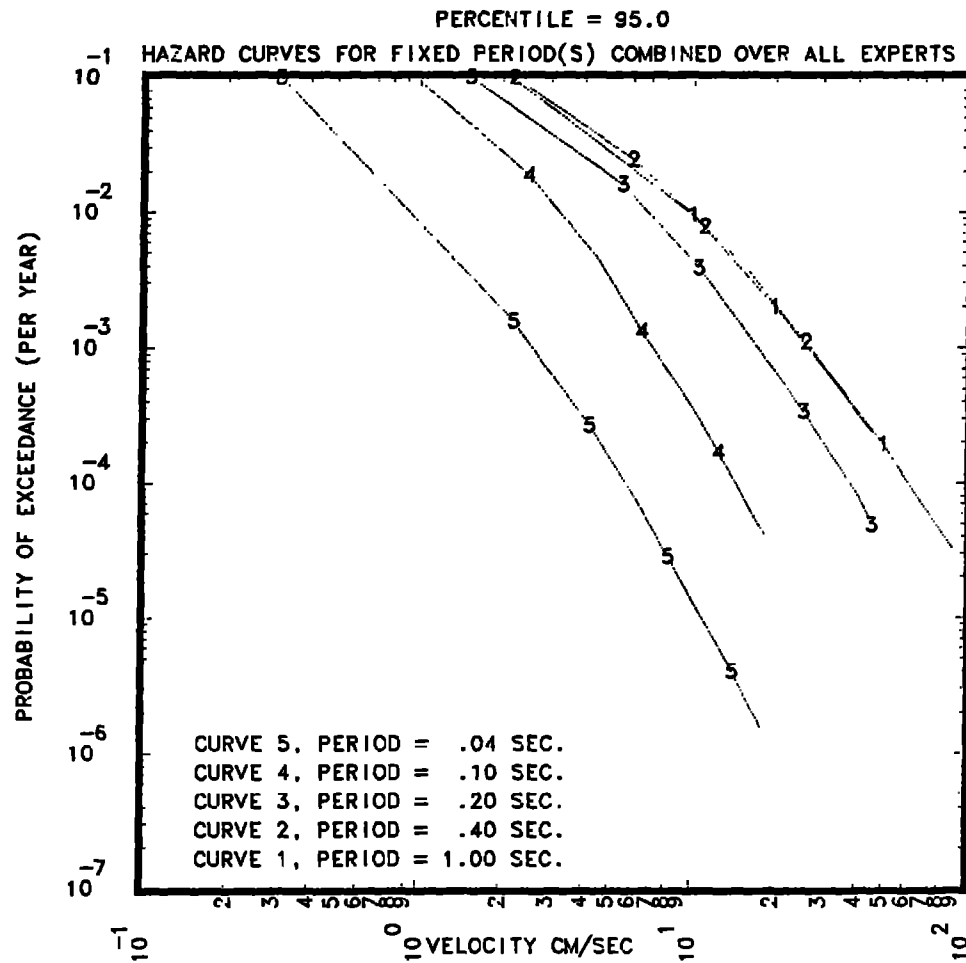
**Fig 15: 15 percent constant percentile hazard curves for the Case 2 (only earthquakes with magnitudes between 5 and 6 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site.**



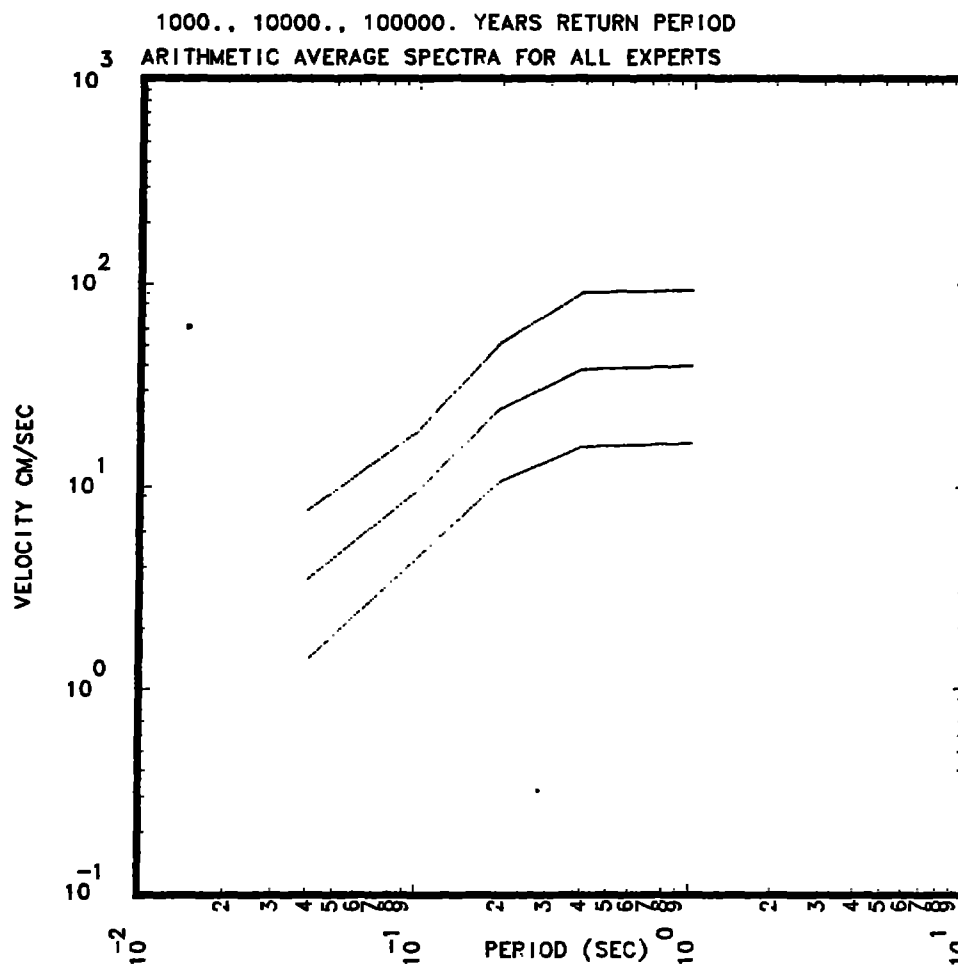
**Fig 16: 50 percent constant percentile hazard curves for the Case 2 (only earthquakes with magnitudes between 5 and 6 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site.**



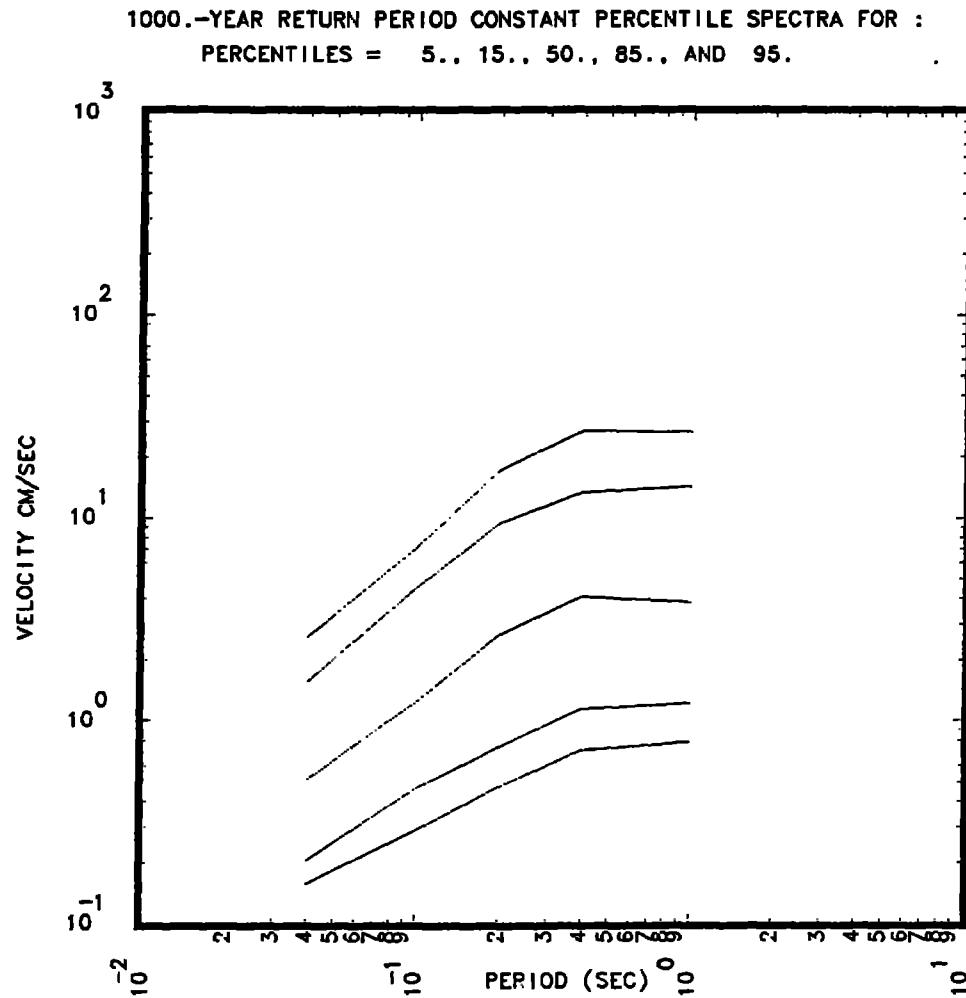
**Fig 17: 85 percent constant percentile hazard curves for the Case 2 (only earthquakes with magnitudes between 5 and 6 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site.**



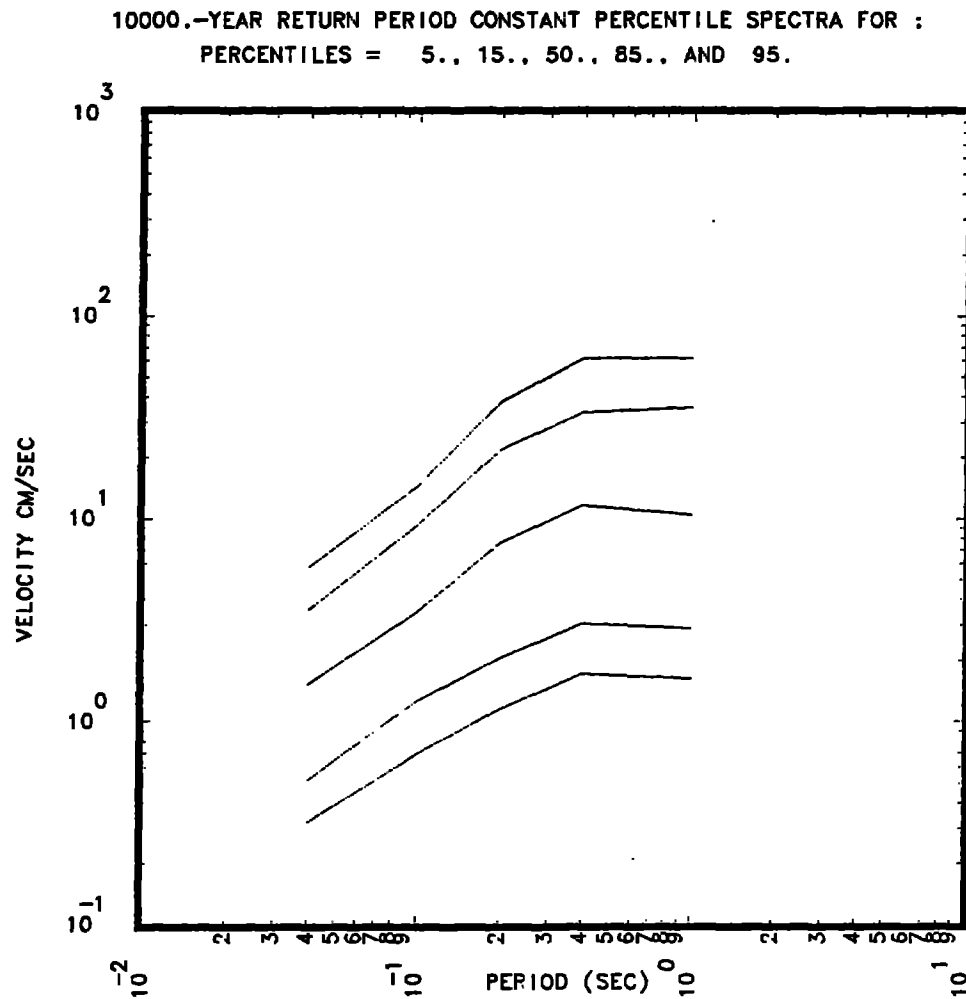
**Fig 18: 95 percent constant percentile hazard curves for the Case 2 (only earthquakes with magnitudes between 5 and 6 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site.**



**Fig 19: Arithmetic average Uniform Hazard Spectra for three return periods for the Case 2 (only earthquakes with magnitudes between 5 and 6 contribute to the hazard) for the Savannah River site.**

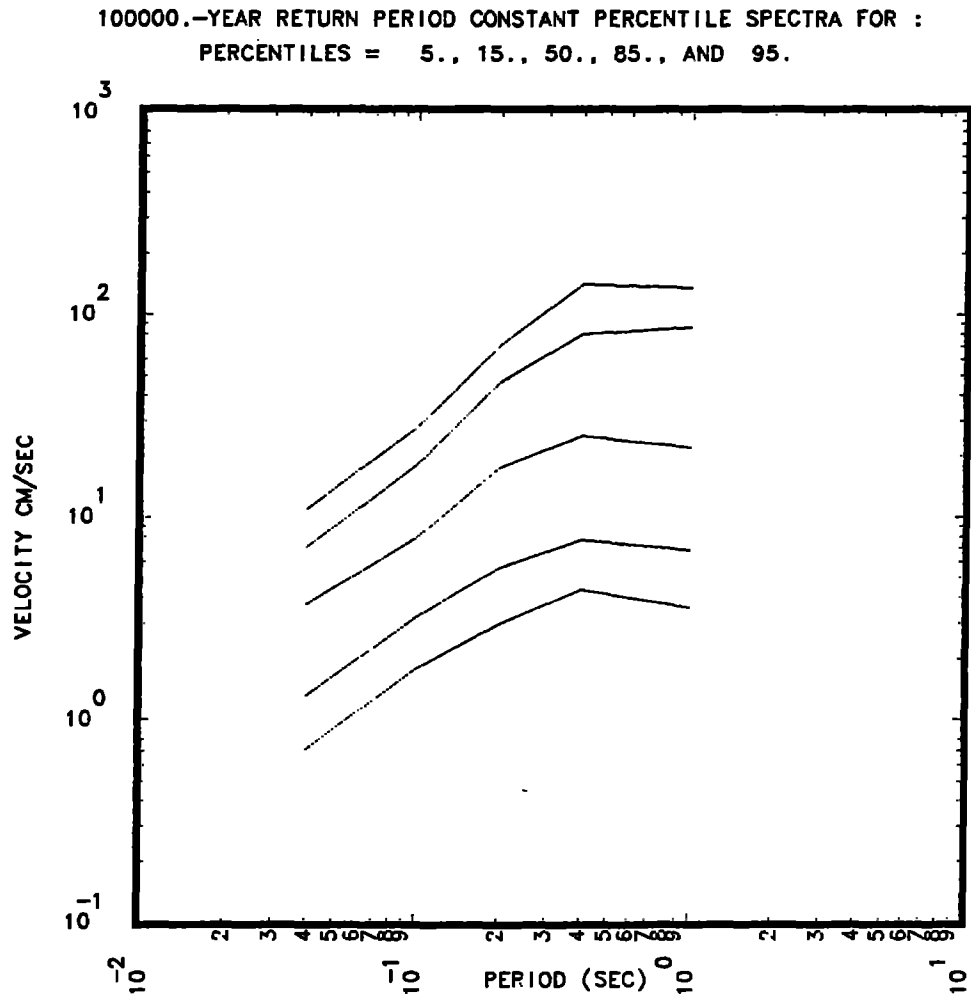


**Fig 20: 5, 15, 50, 85 and 95 percent constant percentile 1000 year return period Uniform Hazard Spectra for the Case 2 (only earthquakes with magnitudes between 5 and 6 contribute to the hazard) for the Savannah River site.**

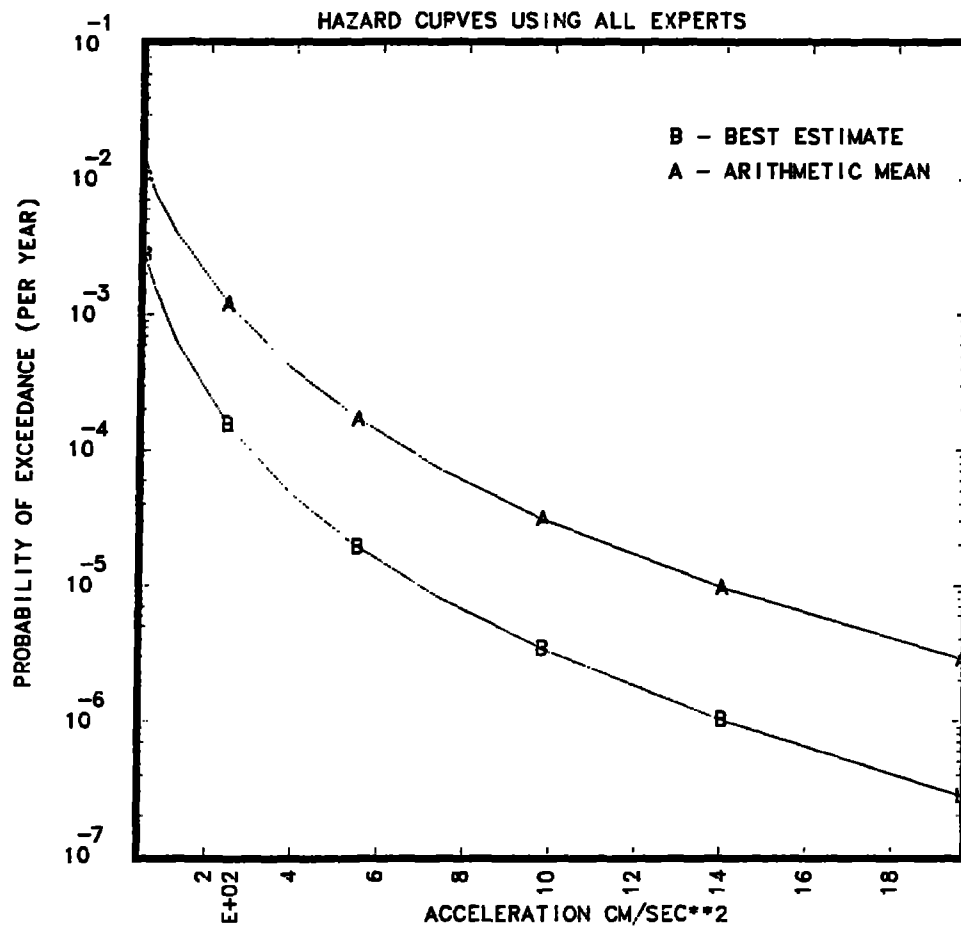


**Fig 21: 5, 15, 50, 85 and 95 percent constant percentile 10,000 year return period Uniform Hazard Spectra for the Case 2 (only earthquakes with magnitudes between 5 and 6 contribute to the hazard) for the Savannah River site.**



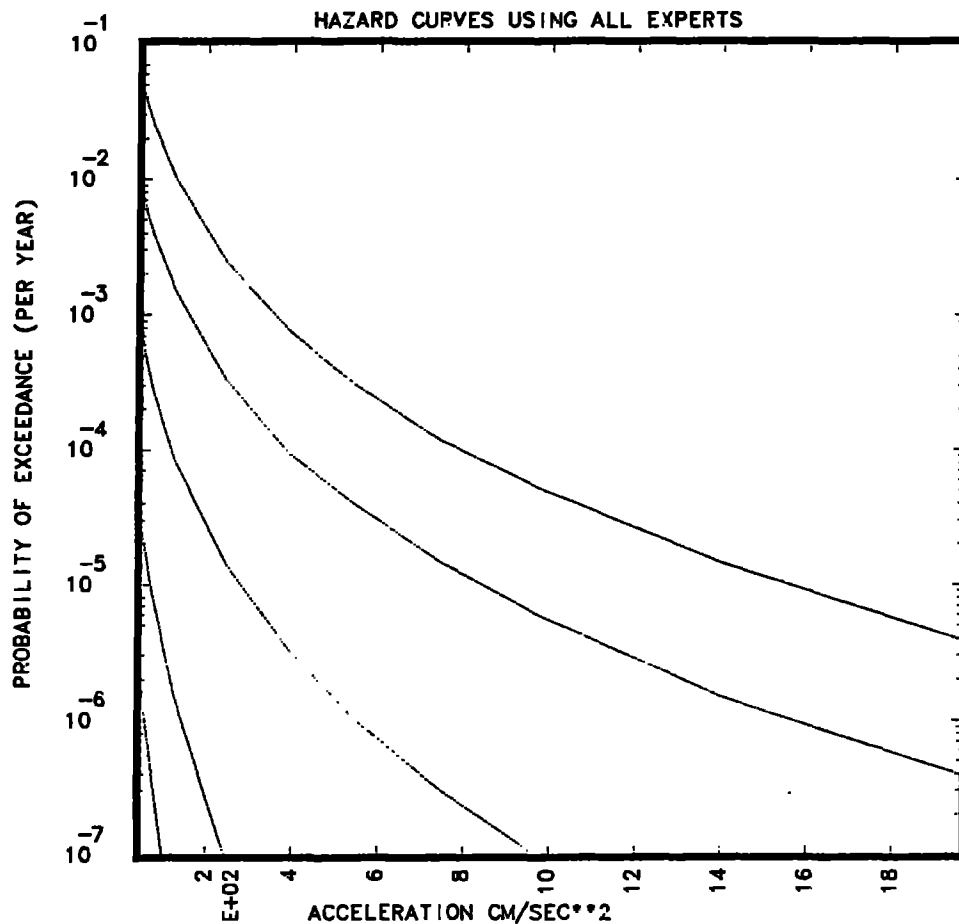


**Fig 22: 5, 15, 50, 85 and 95 percent constant percentile 100,000 year return period Uniform Hazard Spectra for the Case 2 (only earthquakes with magnitudes between 5 and 6 contribute to the hazard) for the Savannah River site.**

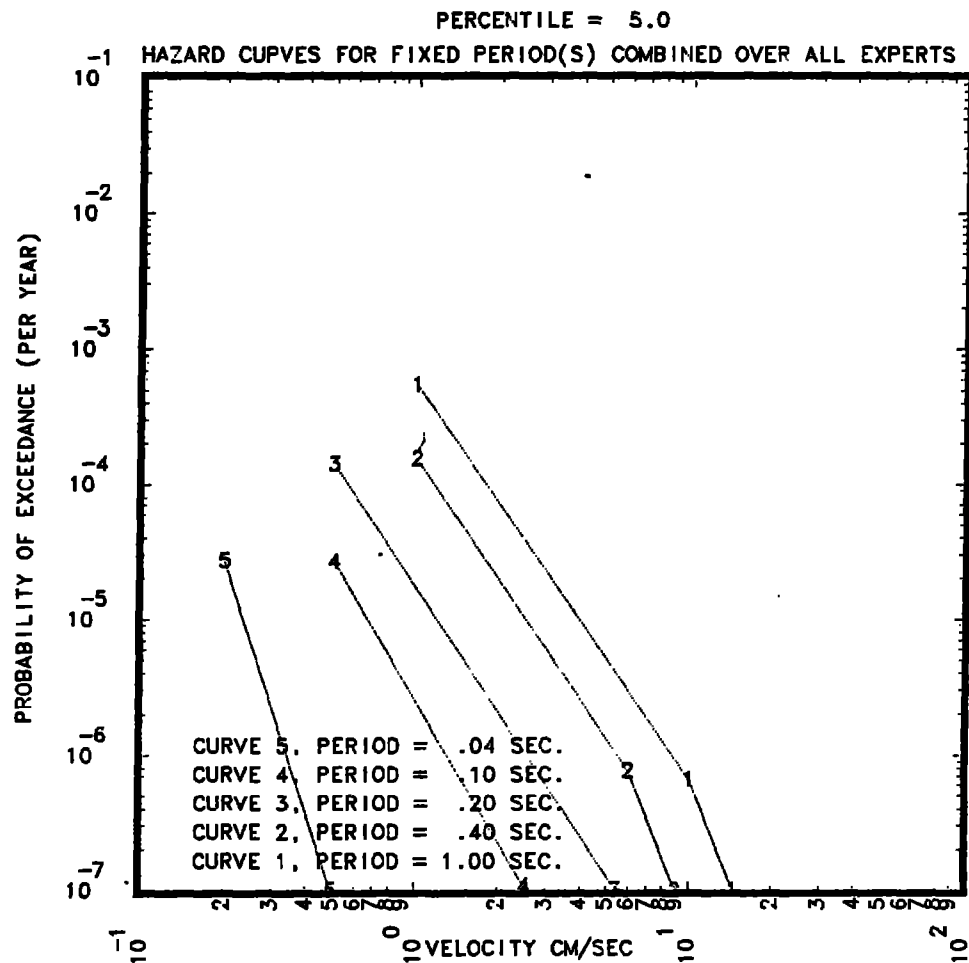


**Fig 23: Best estimate and arithmetic average hazard curves for the Case 3 (only earthquakes greater than magnitude 6.0 contribute to the hazard) of the PGA for the Savannah River site.**

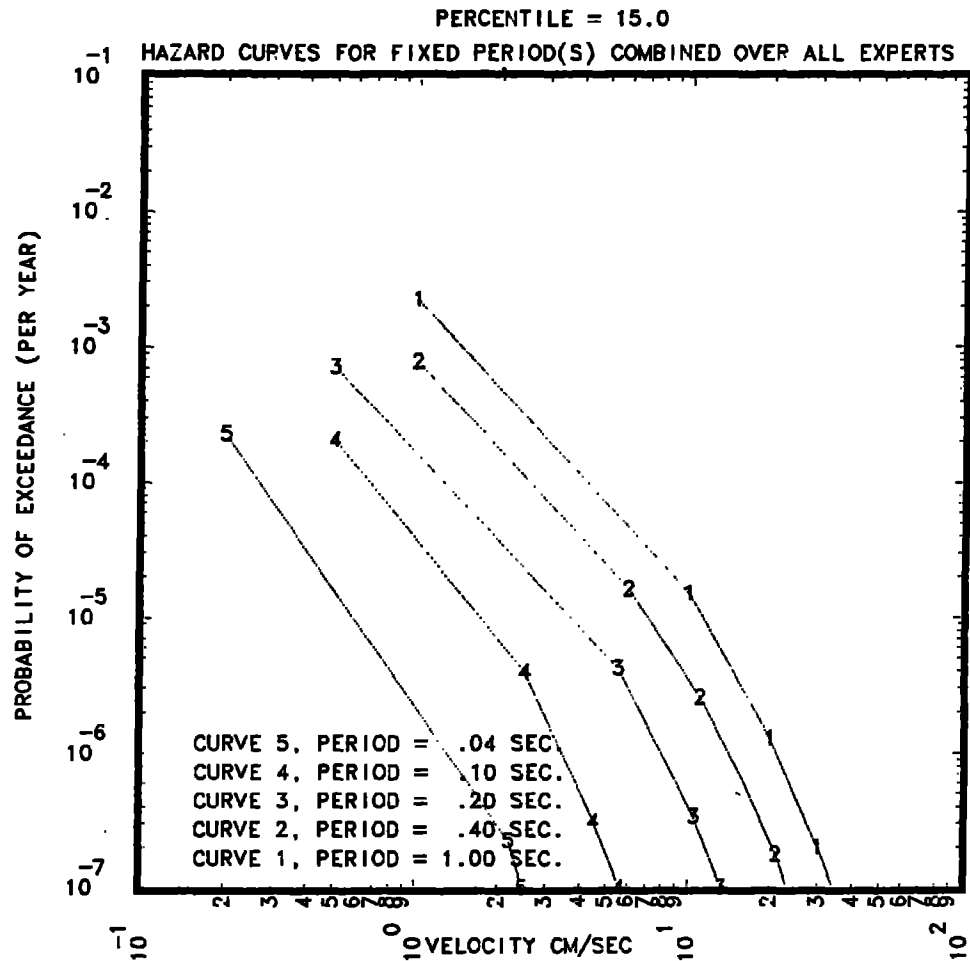
PERCENTILES = 5., 15., 50., 85., AND 95.



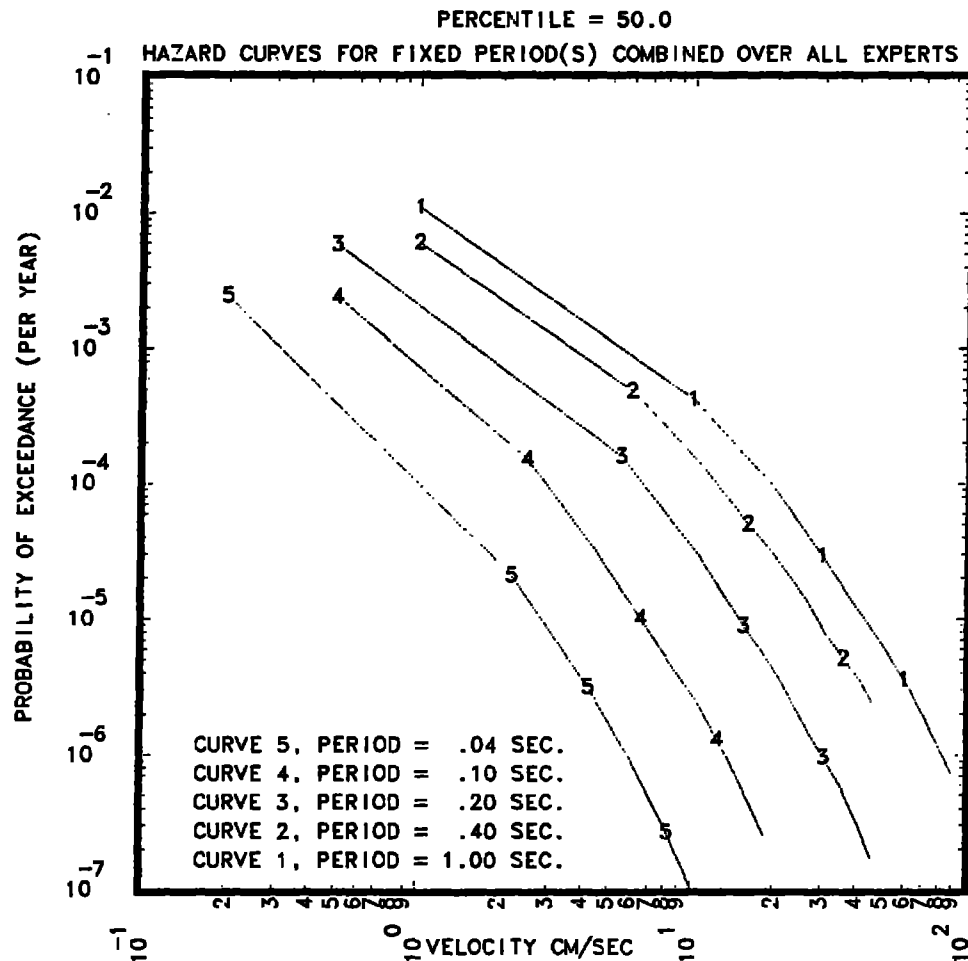
**Fig 24: 5, 15, 50, 85, and 95 percent constant percentile hazard curves for the Case 3 (only earthquakes greater than magnitude 6.0 contribute to the hazard) of the PGA for the Savannah River site.**



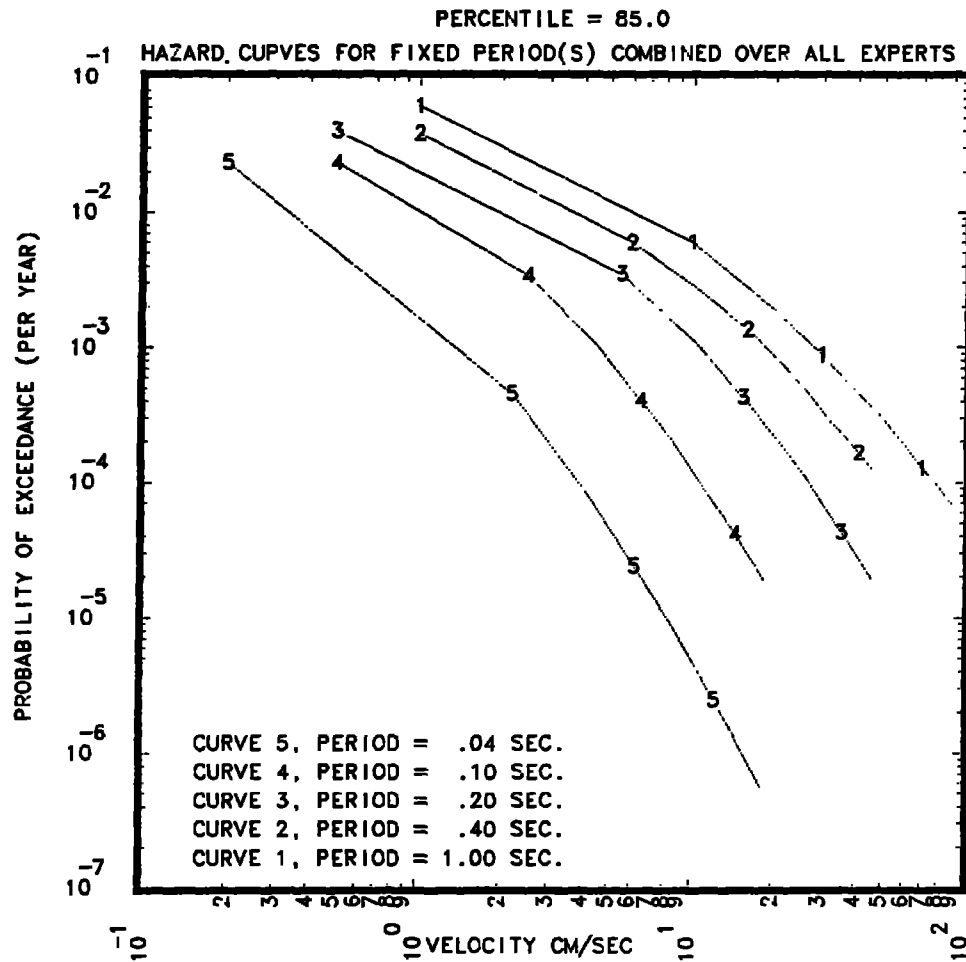
**Fig 25: 5 percent constant percentile hazard curves for the Case 3 (only earthquakes greater than magnitude 6.0 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site.**



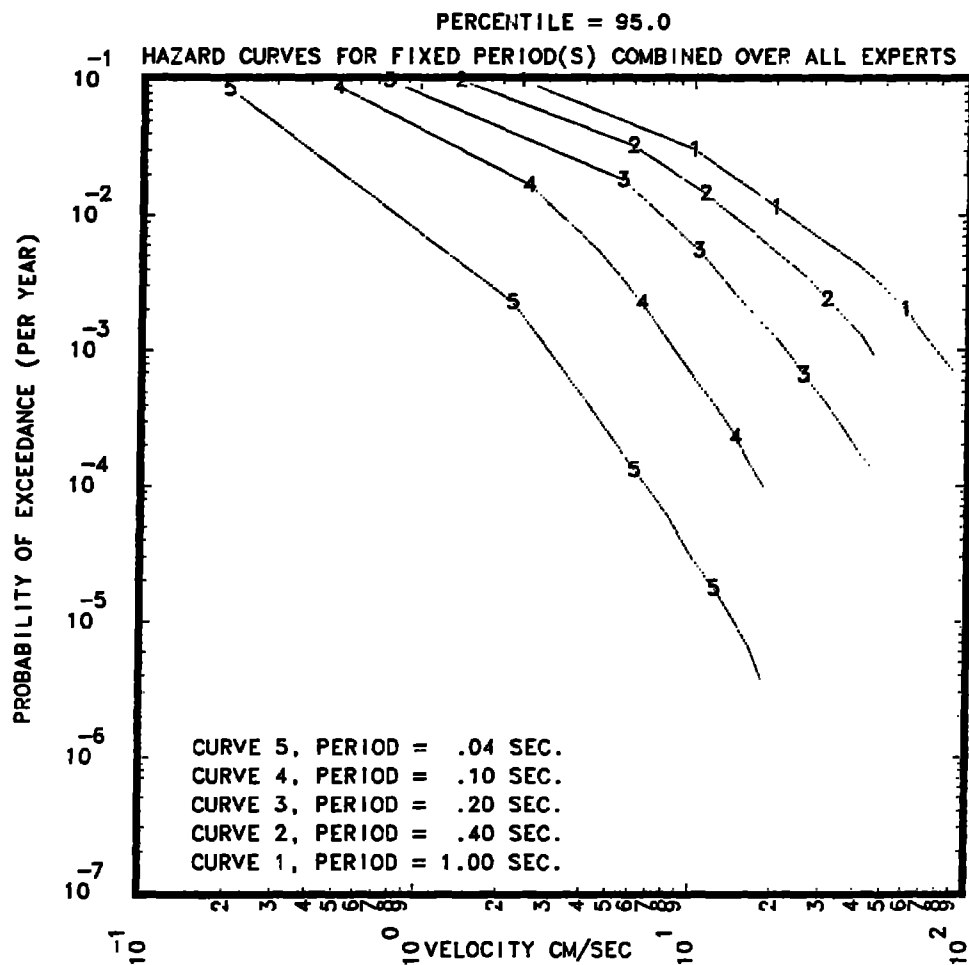
**Fig 26: 15 percent constant percentile hazard curves for the Case 3 (only earthquakes greater than magnitude 6.0 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site.**



**Fig 27: 50 percent constant percentile hazard curves for the Case 3 (only earthquakes greater than magnitude 6.0 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site.**

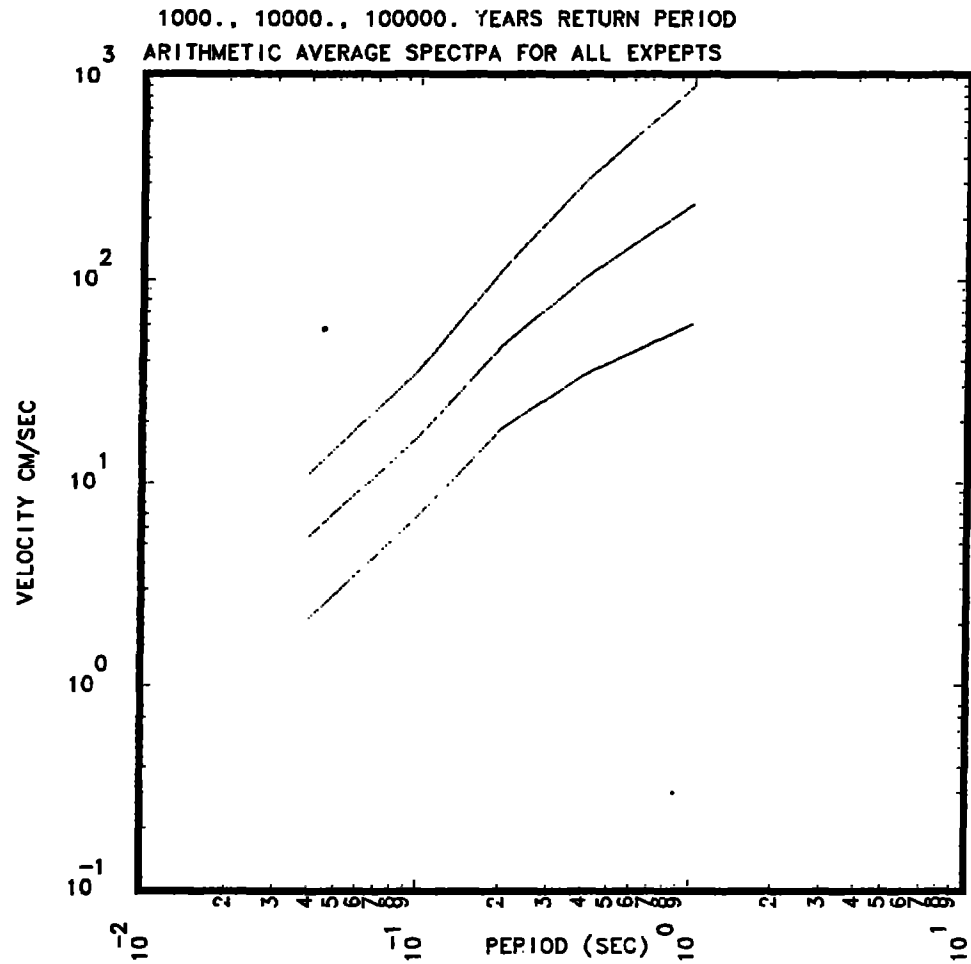


**Fig 28: 85 percent constant percentile hazard curves for the Case 3 (only earthquakes greater than magnitude 6.0 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site.**

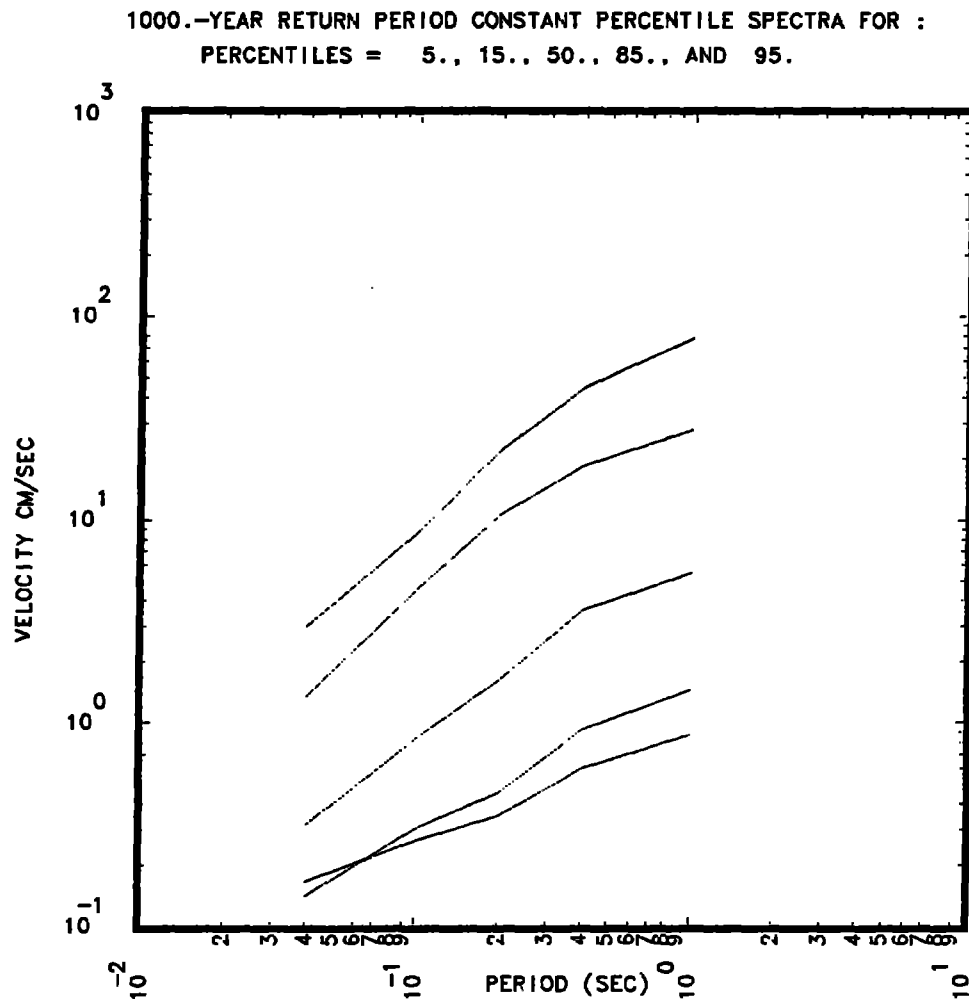


**Fig 29: 95 percent constant percentile hazard curves for the Case 3 (only earthquakes greater than magnitude 6.0 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site.**

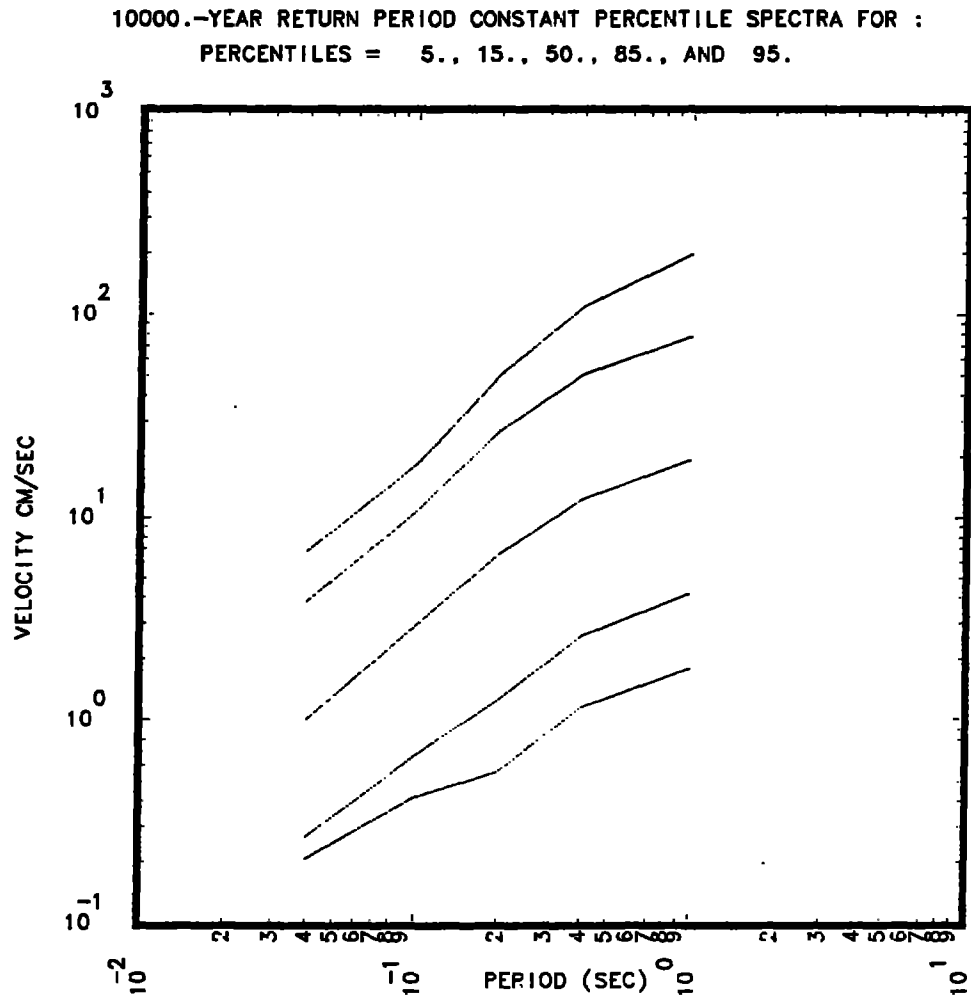




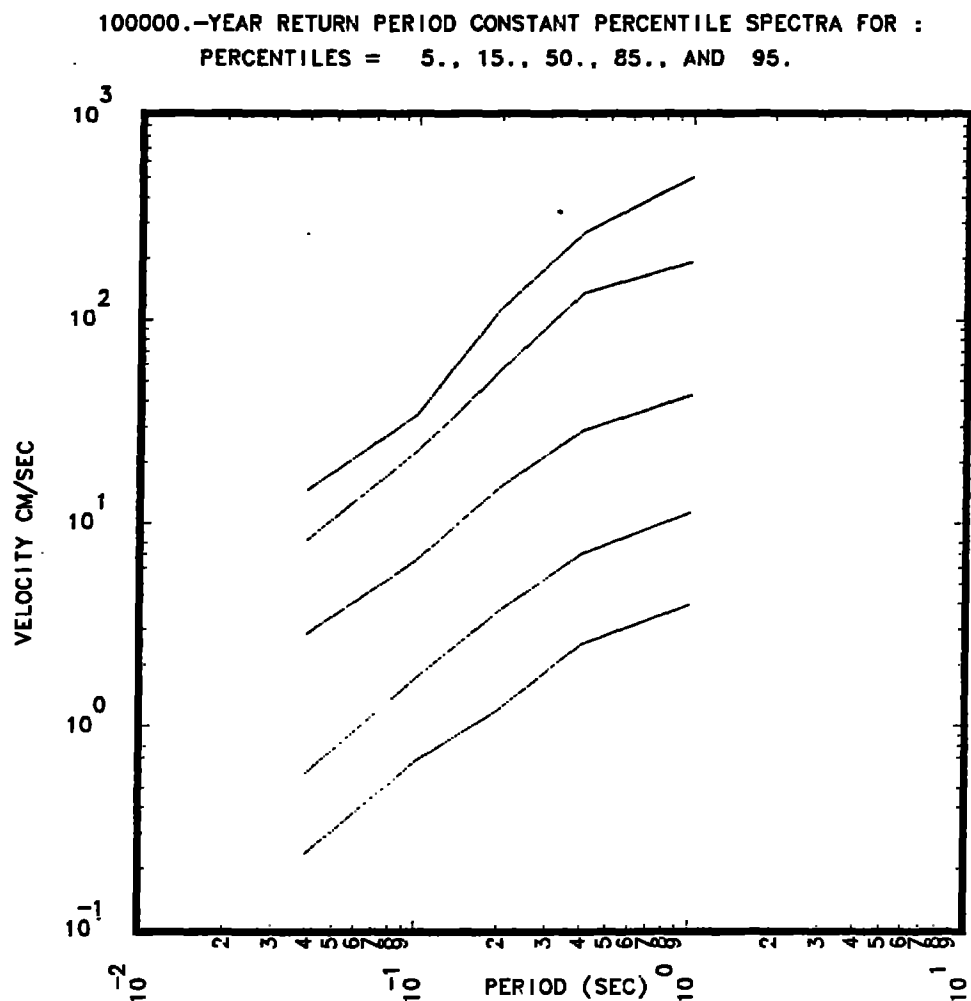
**Fig 30: Arithmetic average Uniform Hazard Spectra for three return periods for the Case 3 (only earthquakes greater than magnitude 6.0 contribute to the hazard) for the Savannah River site.**



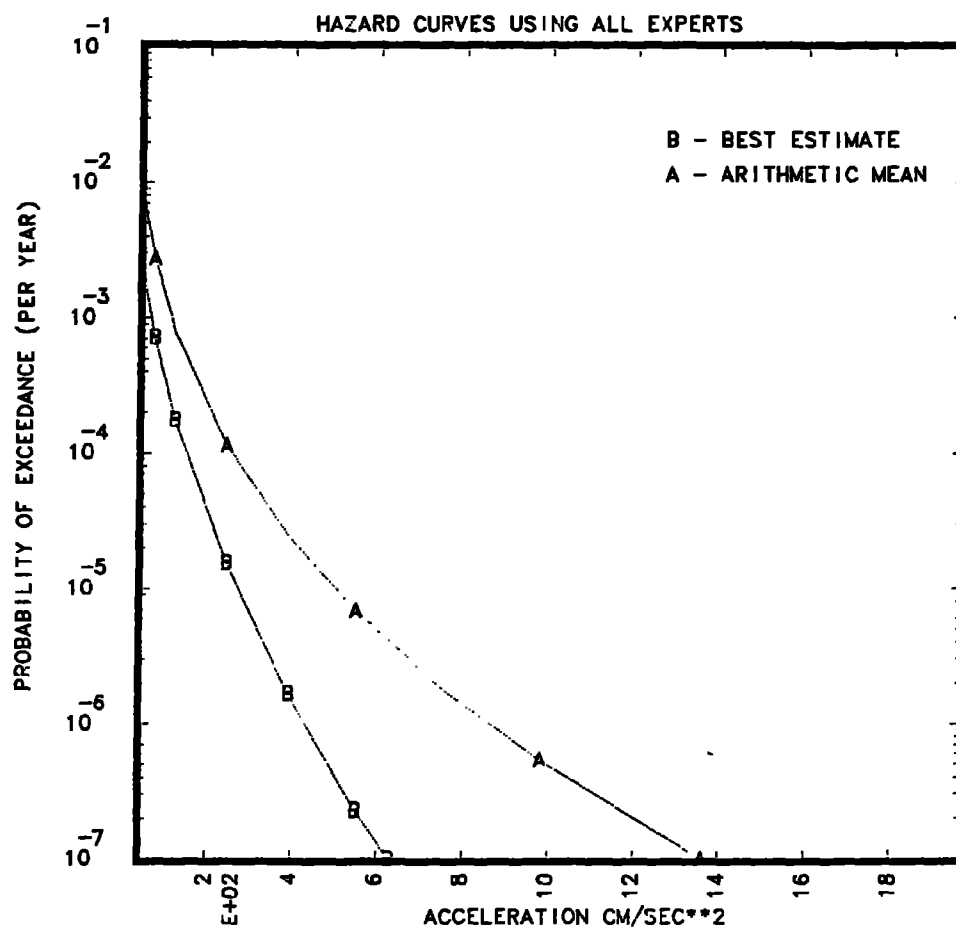
**Fig 31: 5, 15, 50, 85 and 95 percent constant percentile 1000 year return period Uniform Hazard Spectra for the Case 3 (only earthquakes greater than magnitude 6.0 contribute to the hazard) for the Savannah River site.**



**Fig 32: 5, 15, 50, 85 and 95 percent constant percentile 10,000 year return period Uniform Hazard Spectra for the Case 3 (only earthquakes greater than magnitude 6.0 contribute to the hazard) for the Savannah River site.**

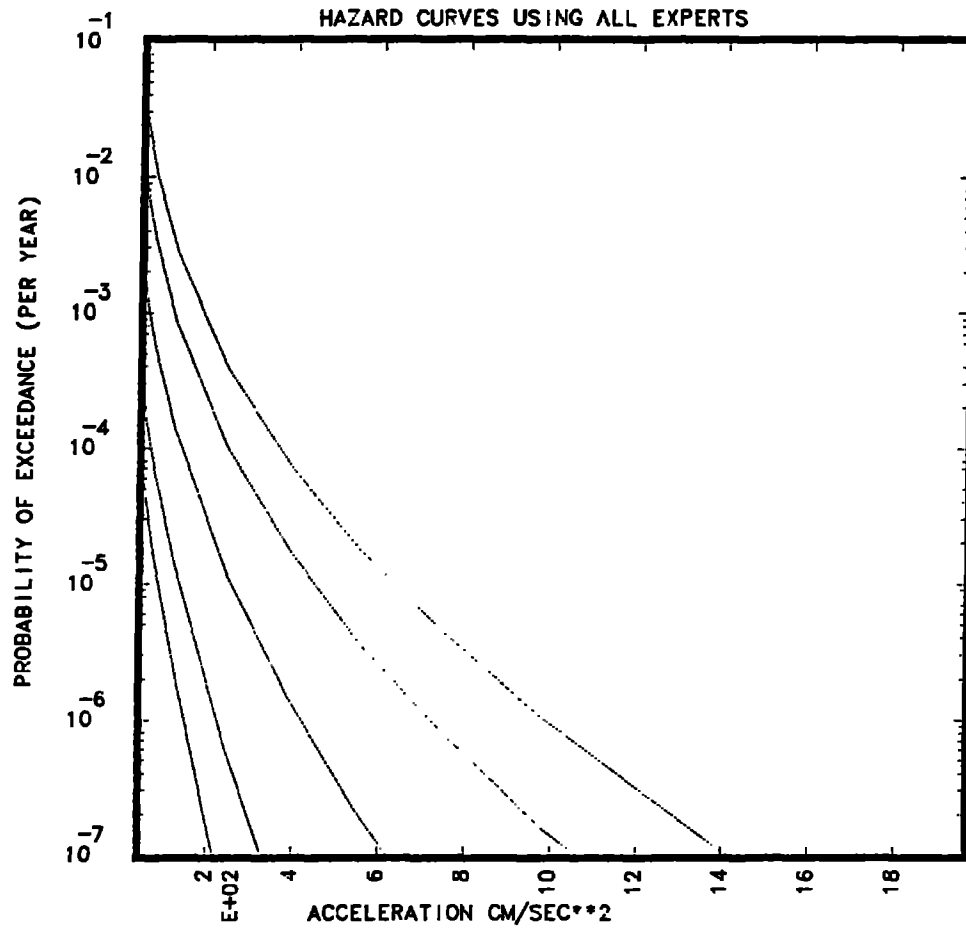


**Fig 33: 5, 15, 50, 85 and 95 percent constant percentile 100,000 year return period Uniform Hazard Spectra for the Case 3 (only earthquakes greater than magnitude 6.0 contribute to the hazard) for the Savannah River site.**

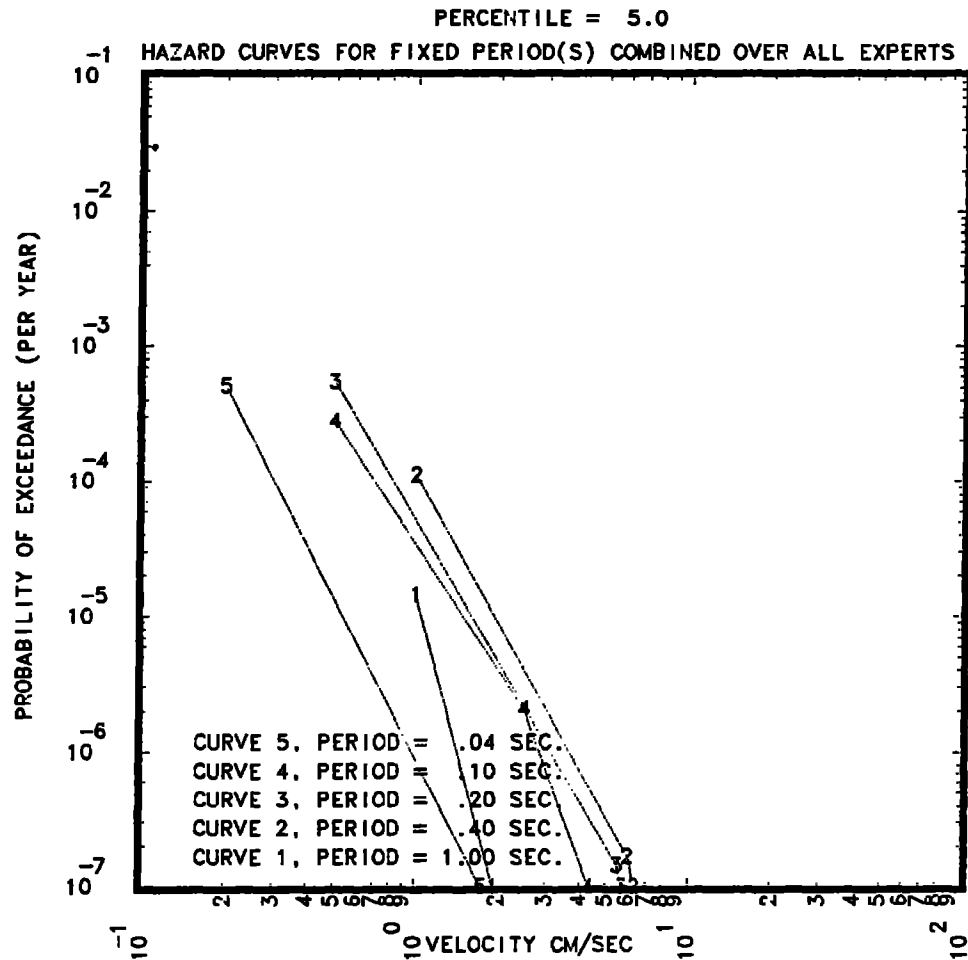


**Fig 34: Best estimate and arithmetic average hazard curves for the Case 4 (only earthquakes with magnitudes between 4.0 and 5.0 contribute to the hazard) of the PGA for the Savannah River site.**

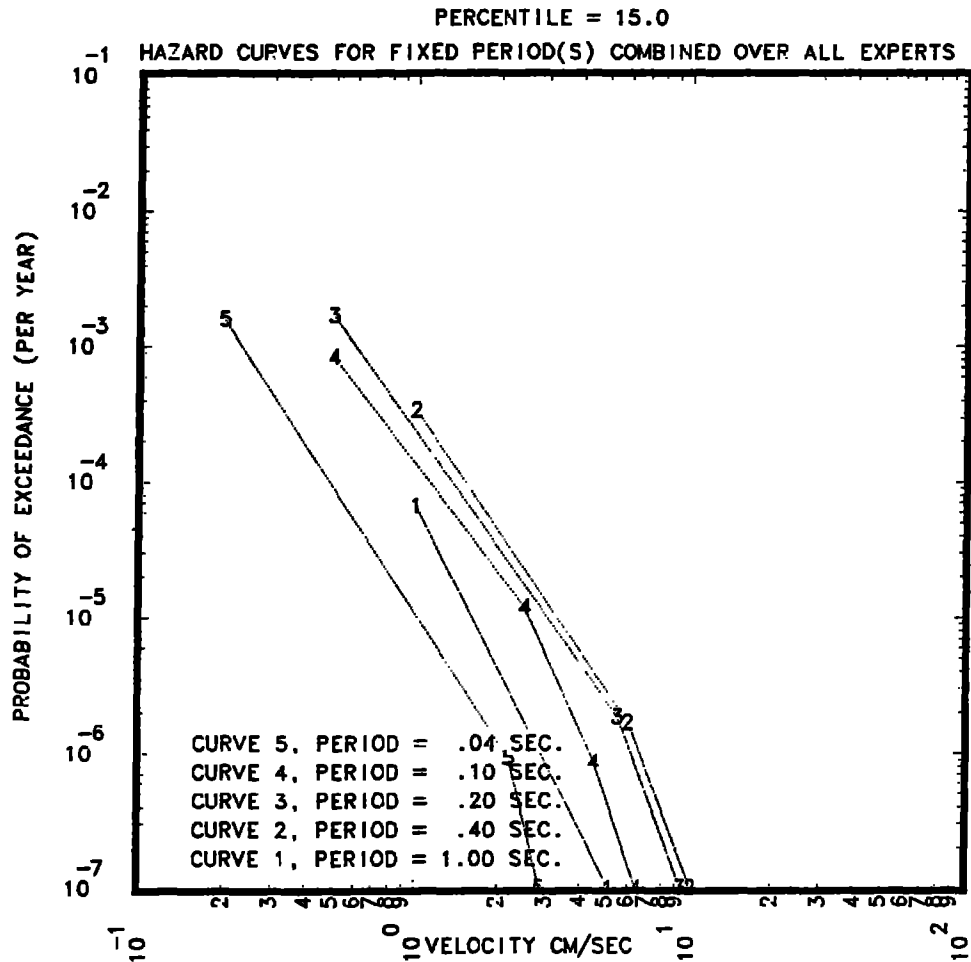
PERCENTILES = 5., 15., 50., 85., AND 95.



**Fig 35: 5, 15, 50, 85, and 95 percent constant percentile hazard curves for the Case 4 (only earthquakes with magnitudes between 4.0 and 5.0 contribute to the hazard) of the PGA for the Savannah River site.**

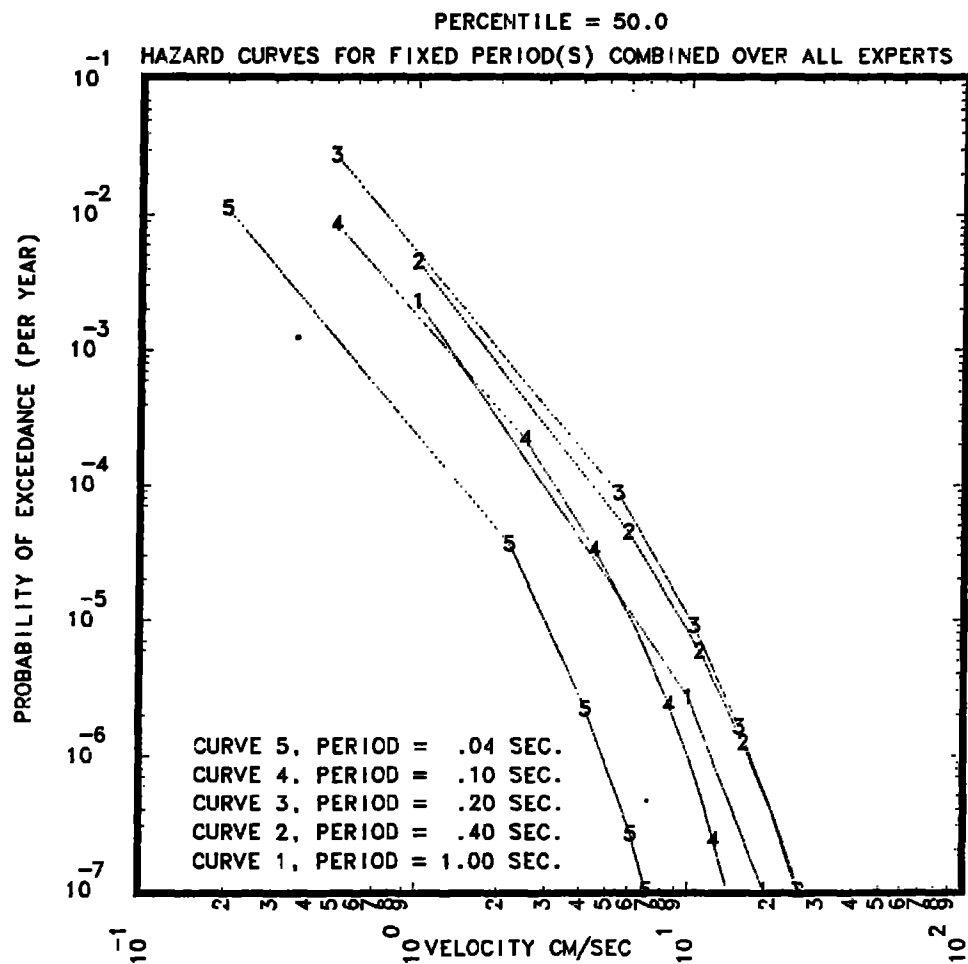


**Fig 36: 5 percent constant percentile hazard curves for the Case 4 (only earthquakes with magnitudes between 4.0 and 5.0 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site.**

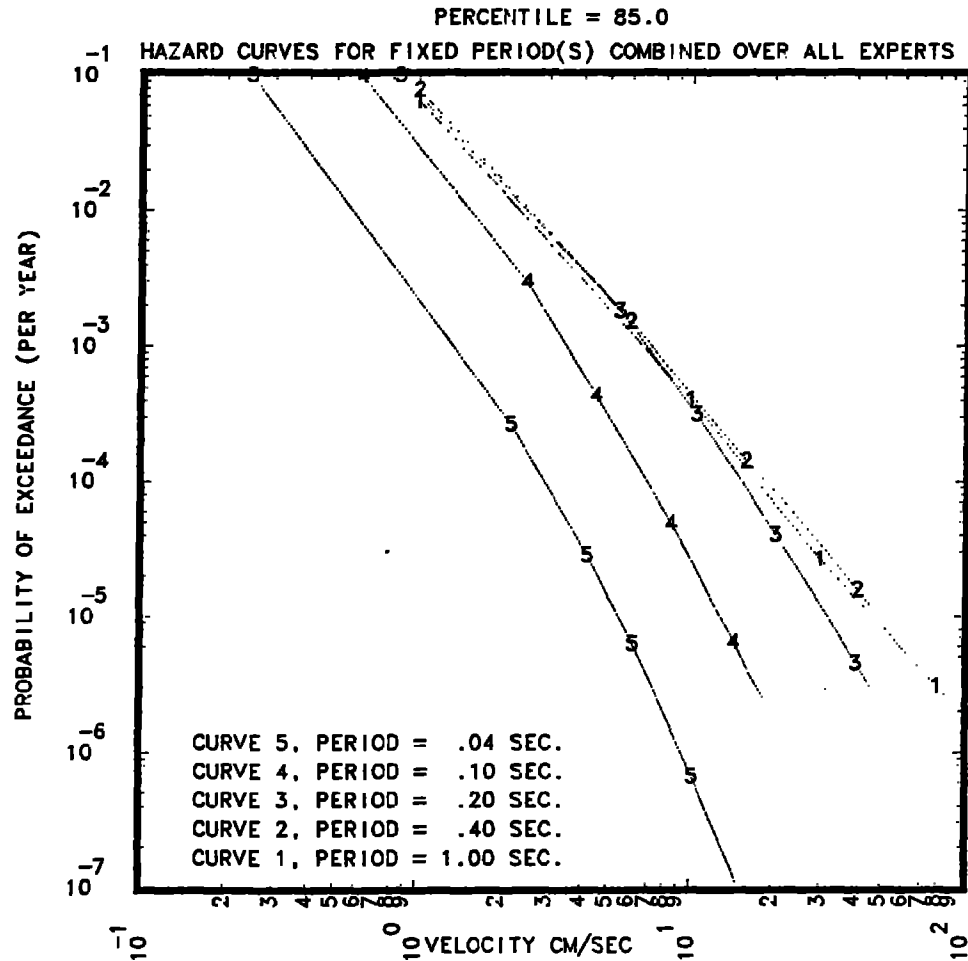


**Fig 37: 15 percent constant percentile hazard curves for the Case 4 (only earthquakes with magnitudes between 4.0 and 5.0 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site.**

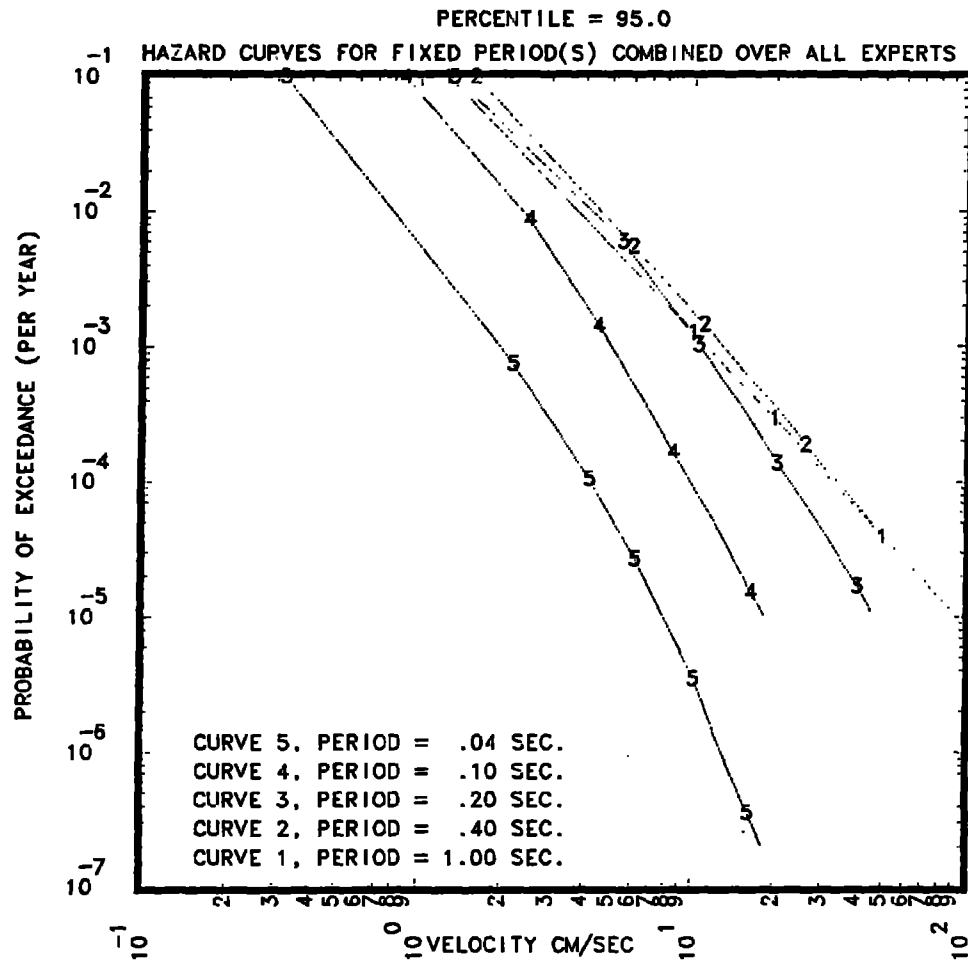




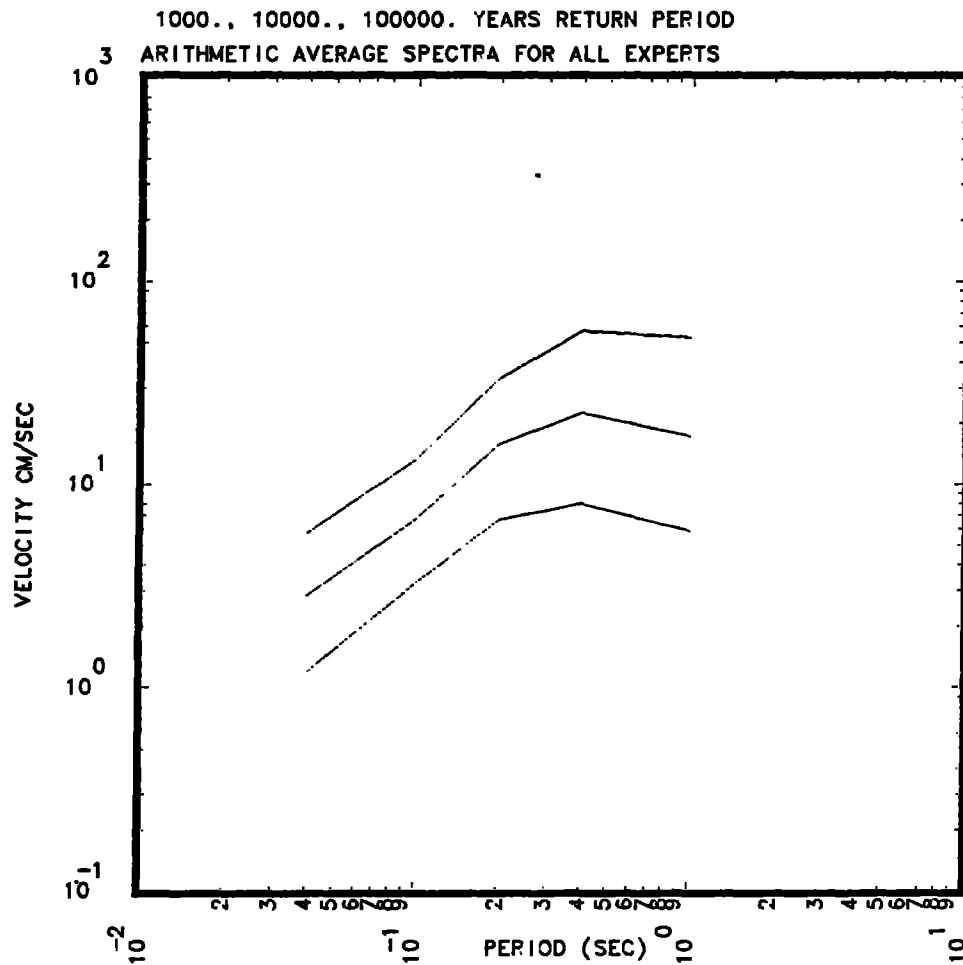
**Fig 38: 50 percent constant percentile hazard curves for the Case 4 (only earthquakes with magnitudes between 4.0 and 5.0 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site.**



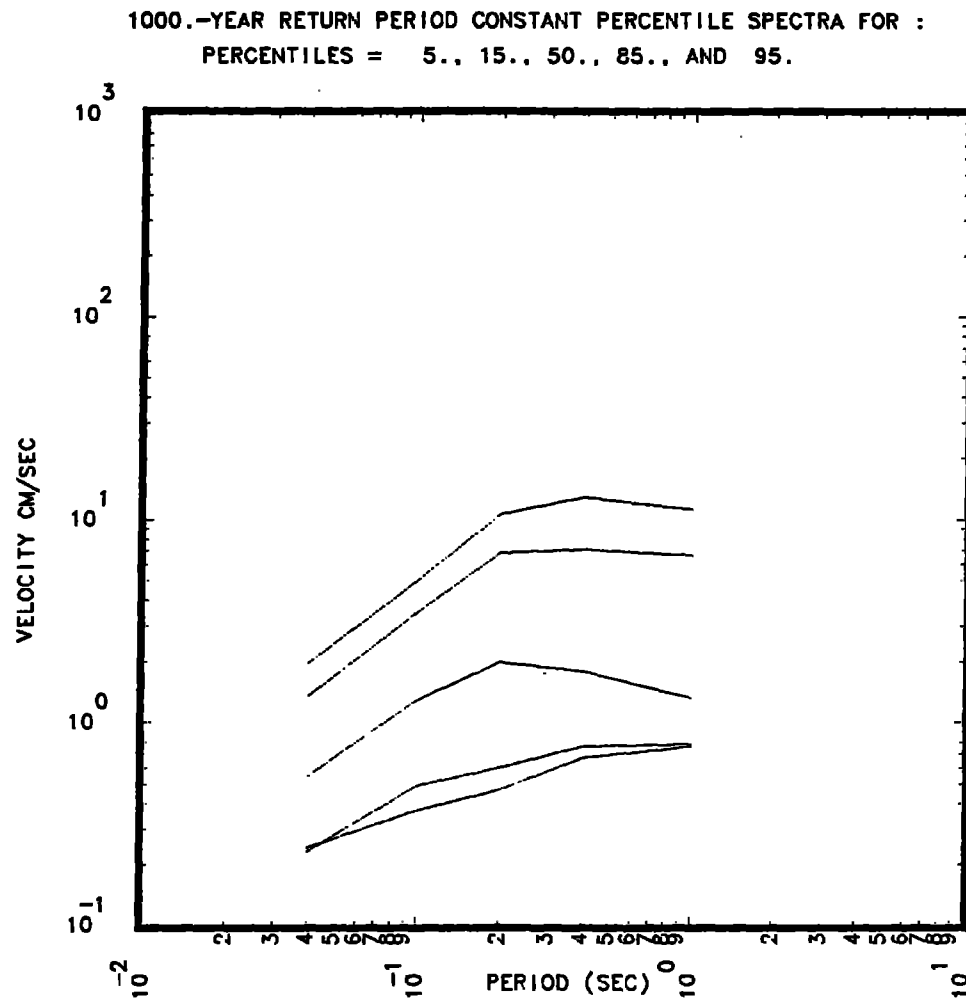
**Fig 39: 85 percent constant percentile hazard curves for the Case 4 (only earthquakes with magnitudes between 4.0 and 5.0 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site.**



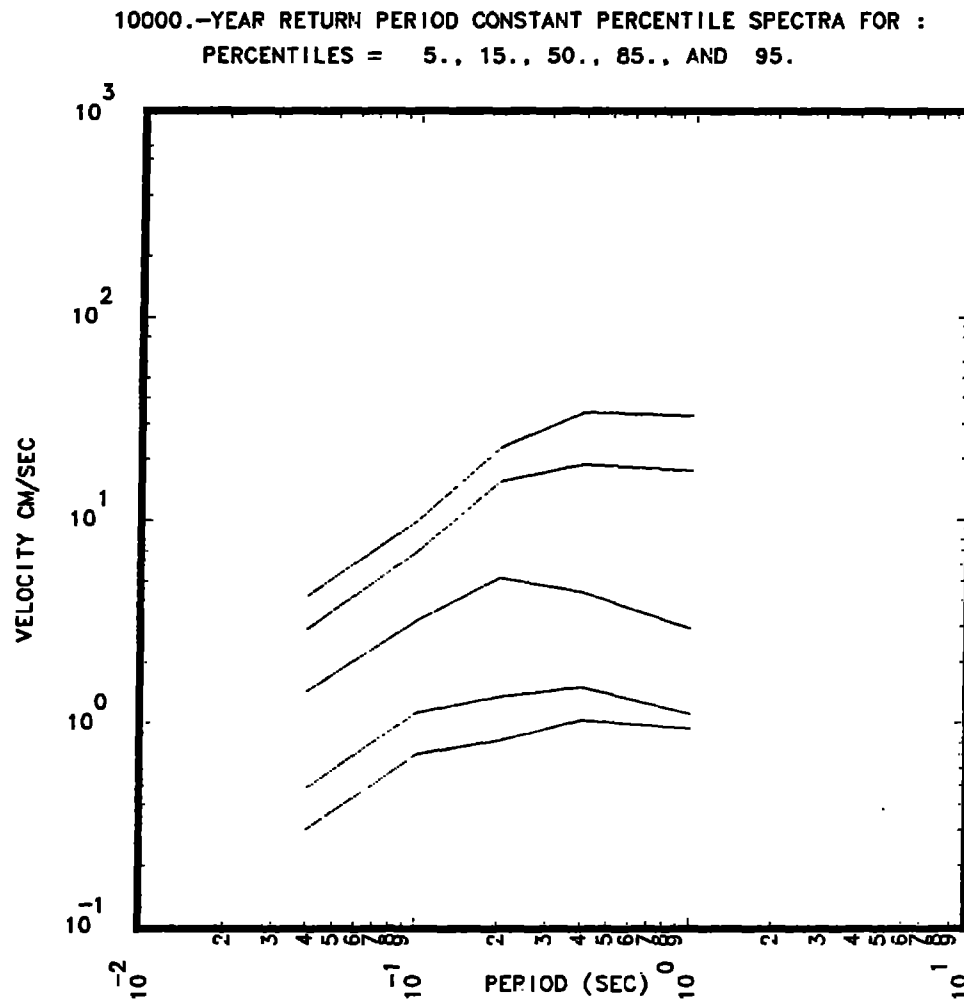
**Fig 40: 95 percent constant percentile hazard curves for the Case 4 (only earthquakes with magnitudes between 4.0 and 5.0 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site.**



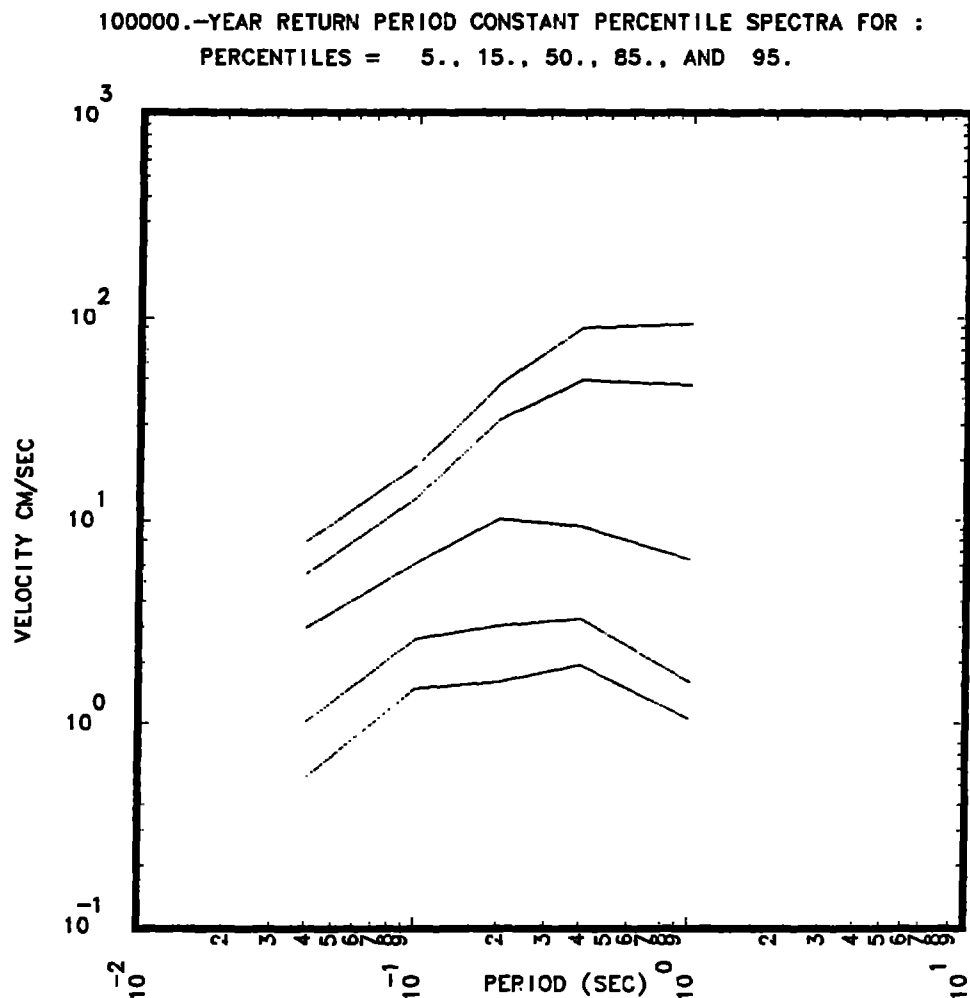
**Fig 41: Arithmetic average Uniform Hazard Spectra for three return periods for the Case 4 (only earthquakes with magnitudes between 4.0 and 5.0 contribute to the hazard) for the Savannah River site.**



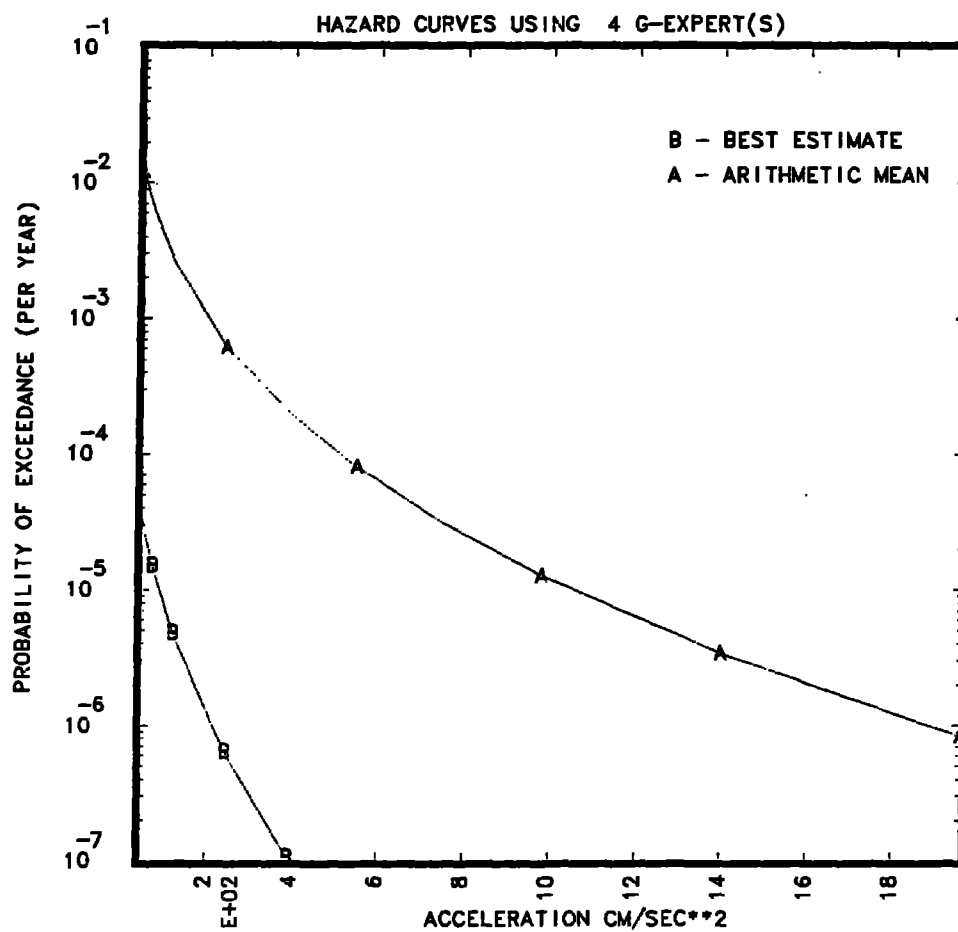
**Fig 42: 5, 15, 50, 85 and 95 percent constant percentile 1000 year return period Uniform Hazard Spectra for the Case 4 (only earthquakes with magnitudes between 4.0 and 5.0 contribute to the hazard) for the Savannah River site.**



**Fig 43: 5, 15, 50, 85 and 95 percent constant percentile 10,000 year return period Uniform Hazard Spectra for the Case 4 (only earthquakes with magnitudes between 4.0 and 5.0 contribute to the hazard) for the Savannah River site.**

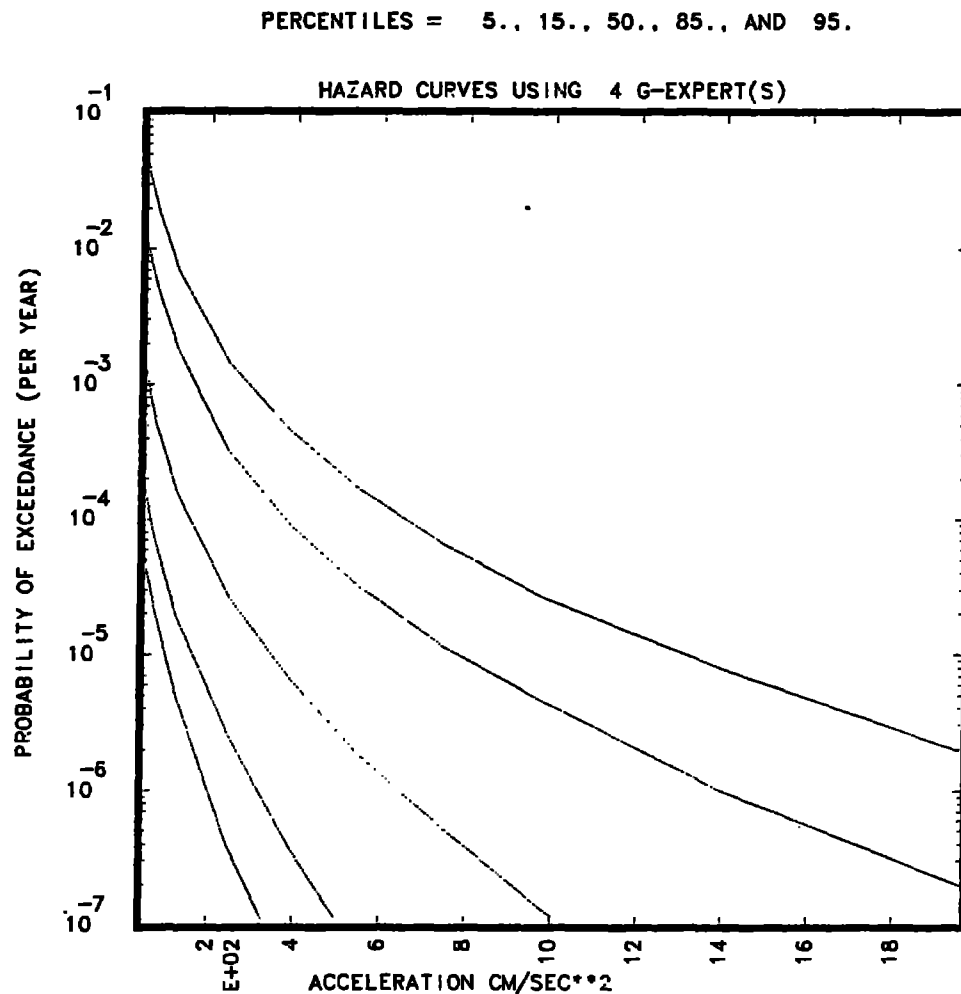


**Fig 44: 5, 15, 50, 85 and 95 percent constant percentile 100,000 year return period Uniform Hazard Spectra for the Case 4 (only earthquakes with magnitudes between 4.0 and 5.0 contribute to the hazard) for the Savannah River site.**

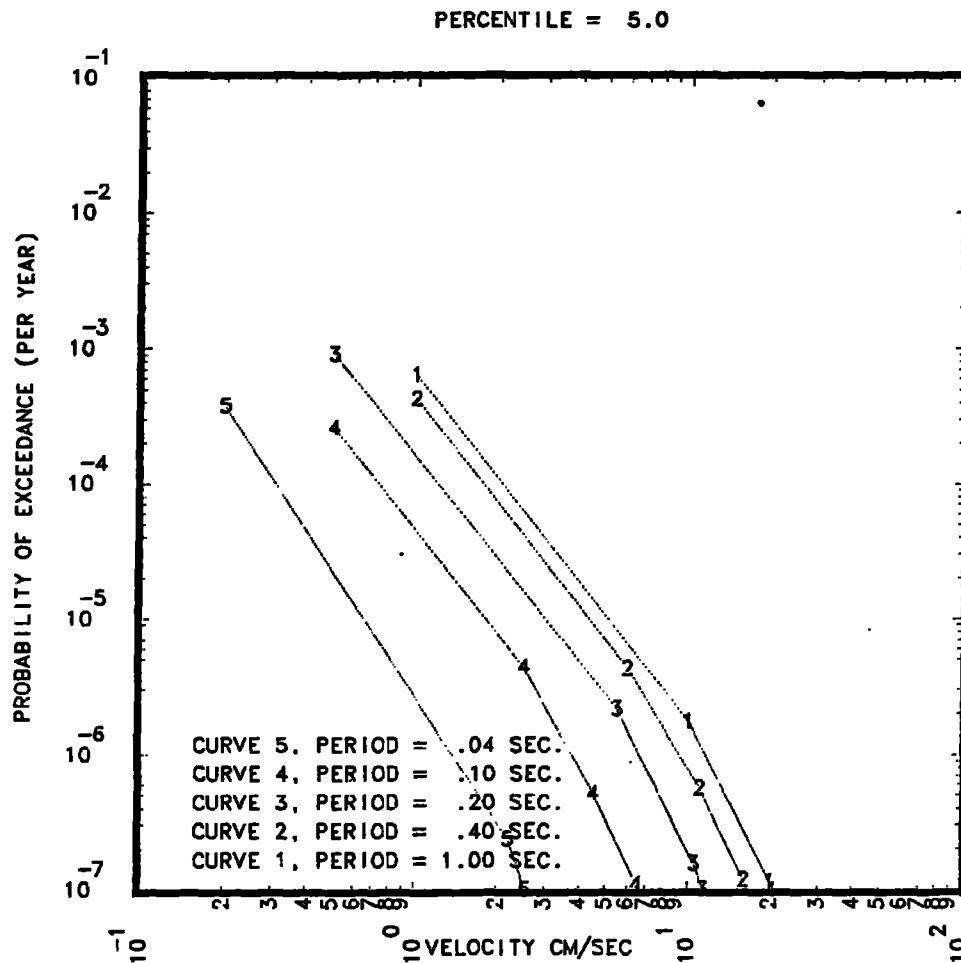


**Fig 45: Best estimate and arithmetic average hazard curves for the base case (Minimum contributing magnitude = 5.0) of the PGA for the Savannah River site when only four ground motion experts' inputs are used.**

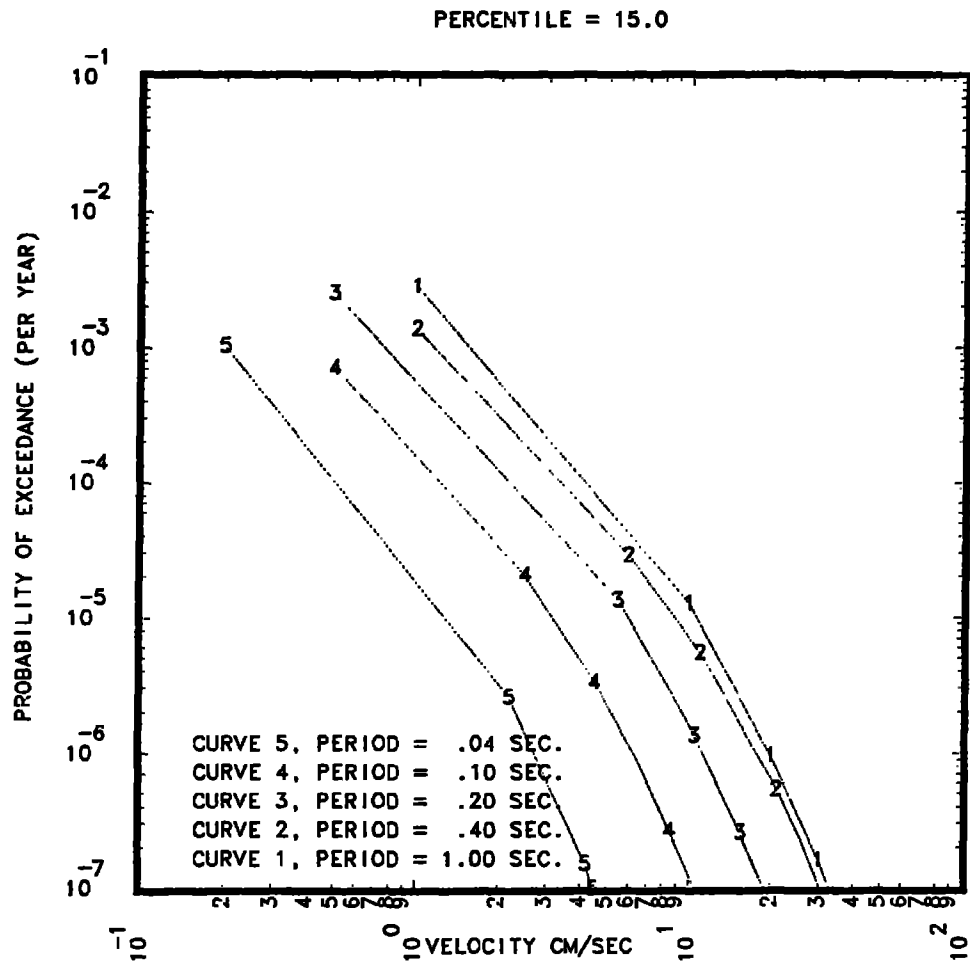




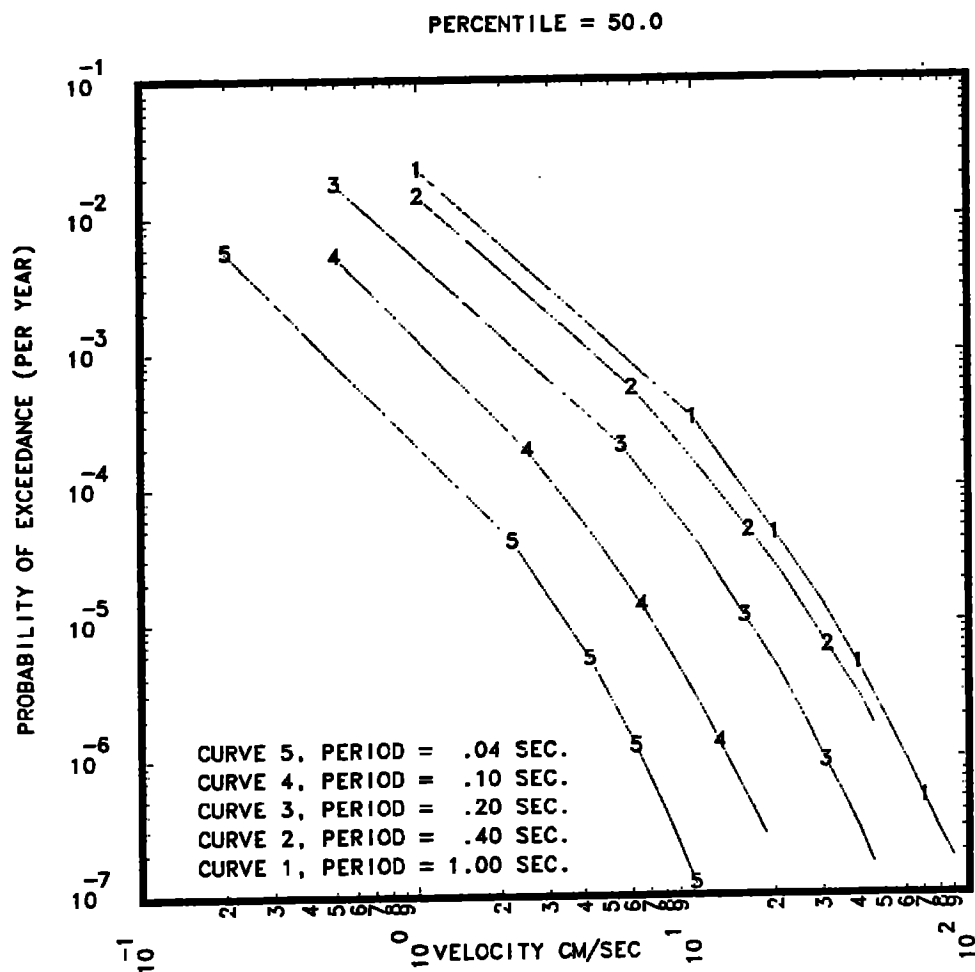
**Fig 46: 5, 15, 50, 85, and 95 percent constant percentile hazard curves for the base case (Minimum contributing magnitude = 5.0) of the PGA for the Savannah River site when only four ground motion experts' inputs are used.**



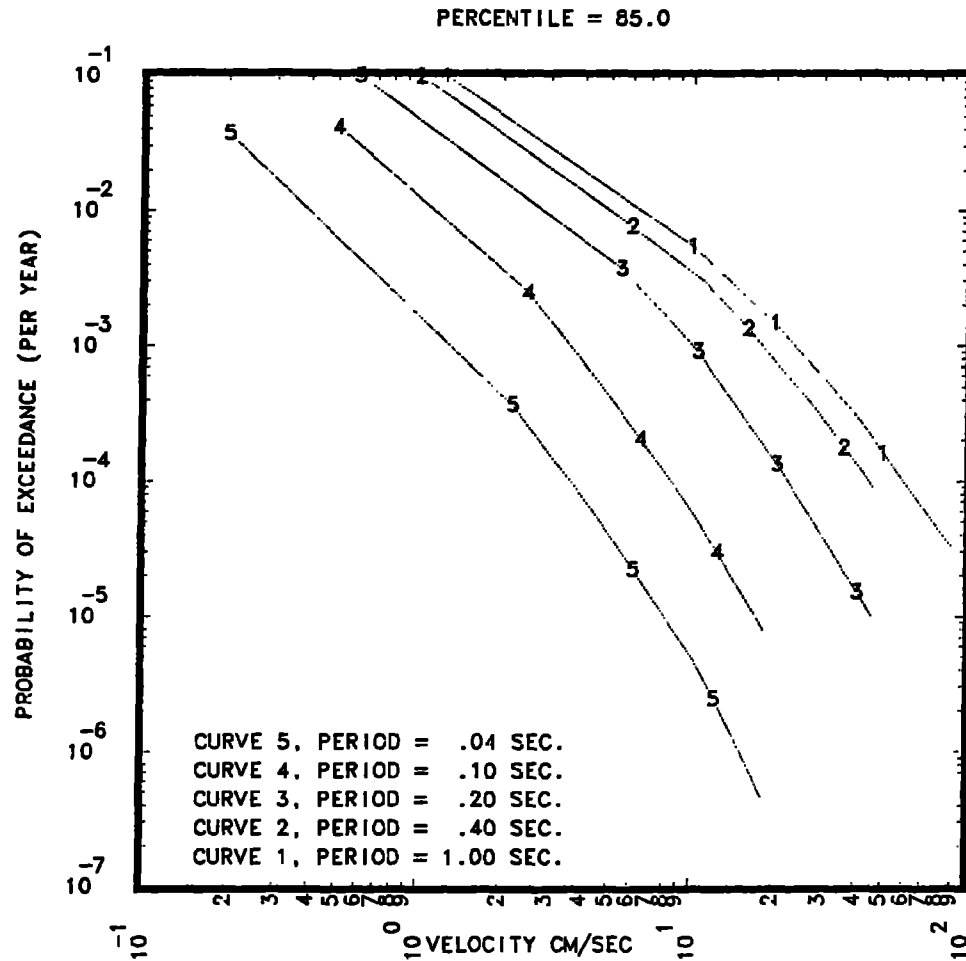
**Fig 47: 5 percent constant percentile hazard curves for the base case (Minimum contributing magnitude = 5.0) of the PSRV at 5 frequencies for the Savannah River site when only four ground motion experts' inputs are used.**



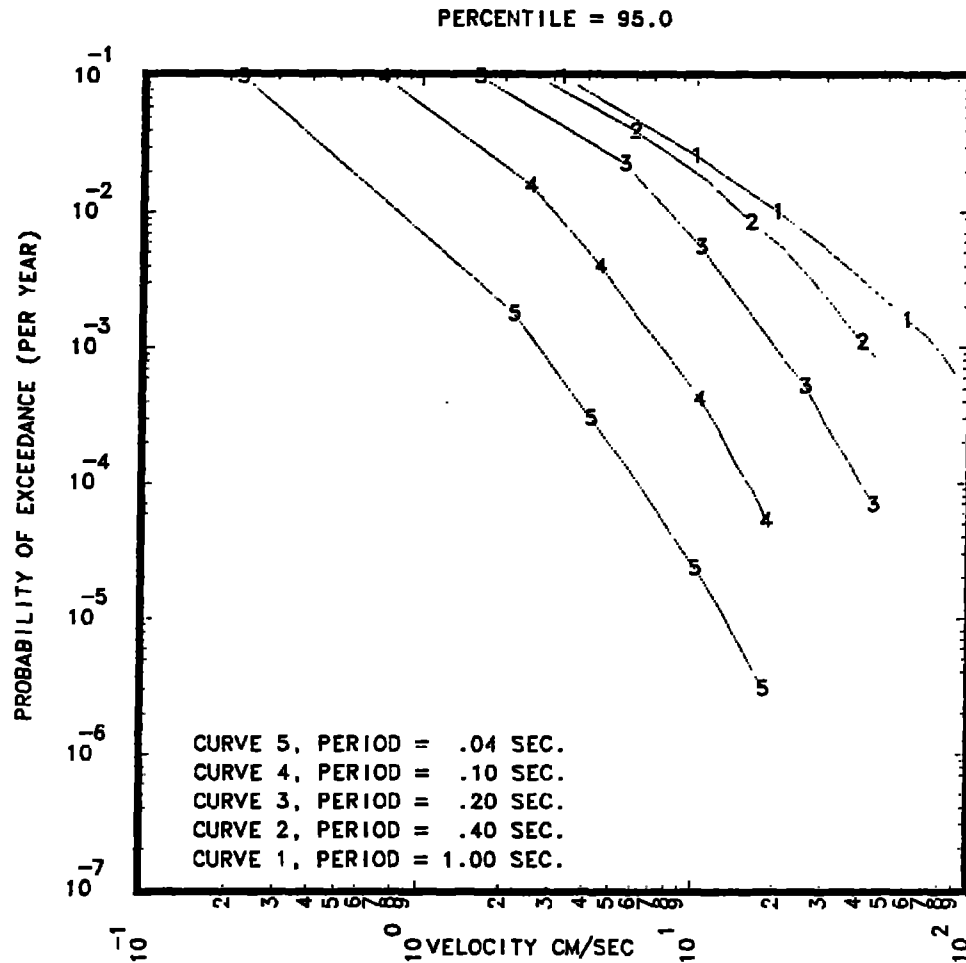
**Fig 48: 15 percent constant percentile hazard curves for the base case (Minimum contributing magnitude = 5.0) of the PSRV at 5 frequencies for the Savannah River site when only four ground motion experts' inputs are used.**



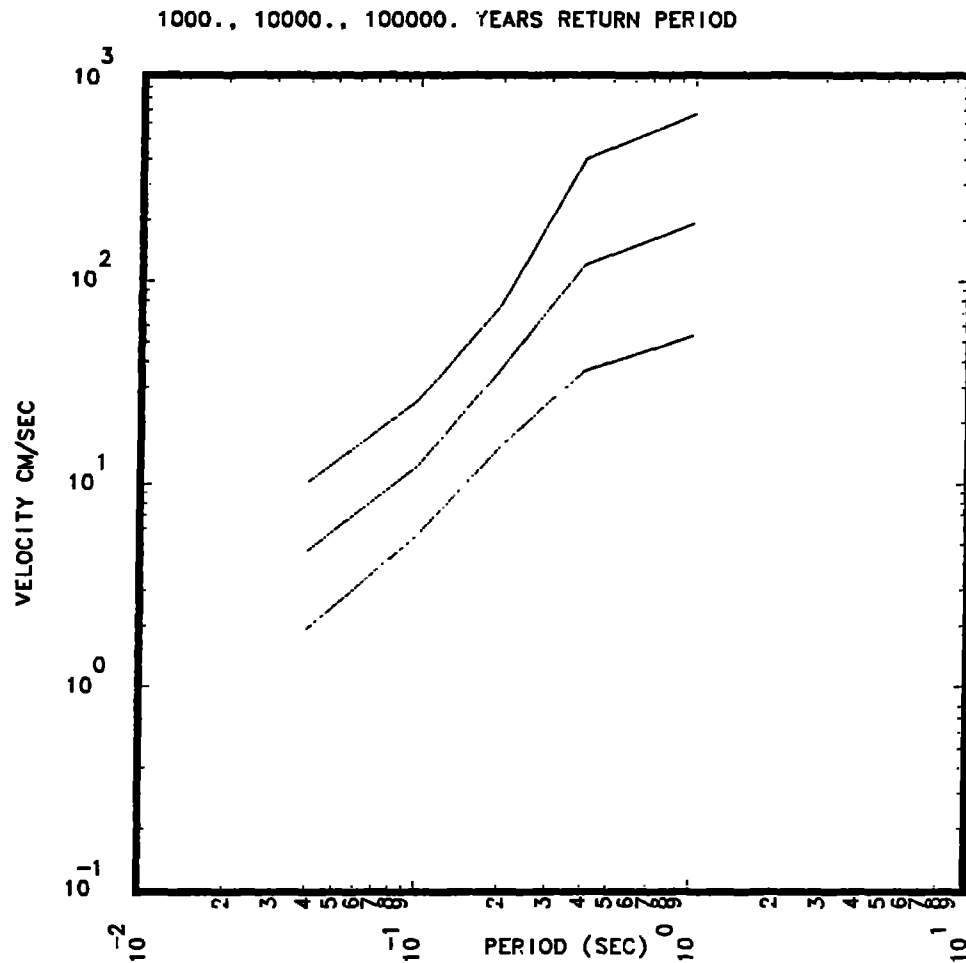
**Fig 49: 50 percent constant percentile hazard curves for the base case (Minimum contributing magnitude = 5.0) of the PSRV at 5 frequencies for the Savannah River site when only four ground motion experts' inputs are used.**



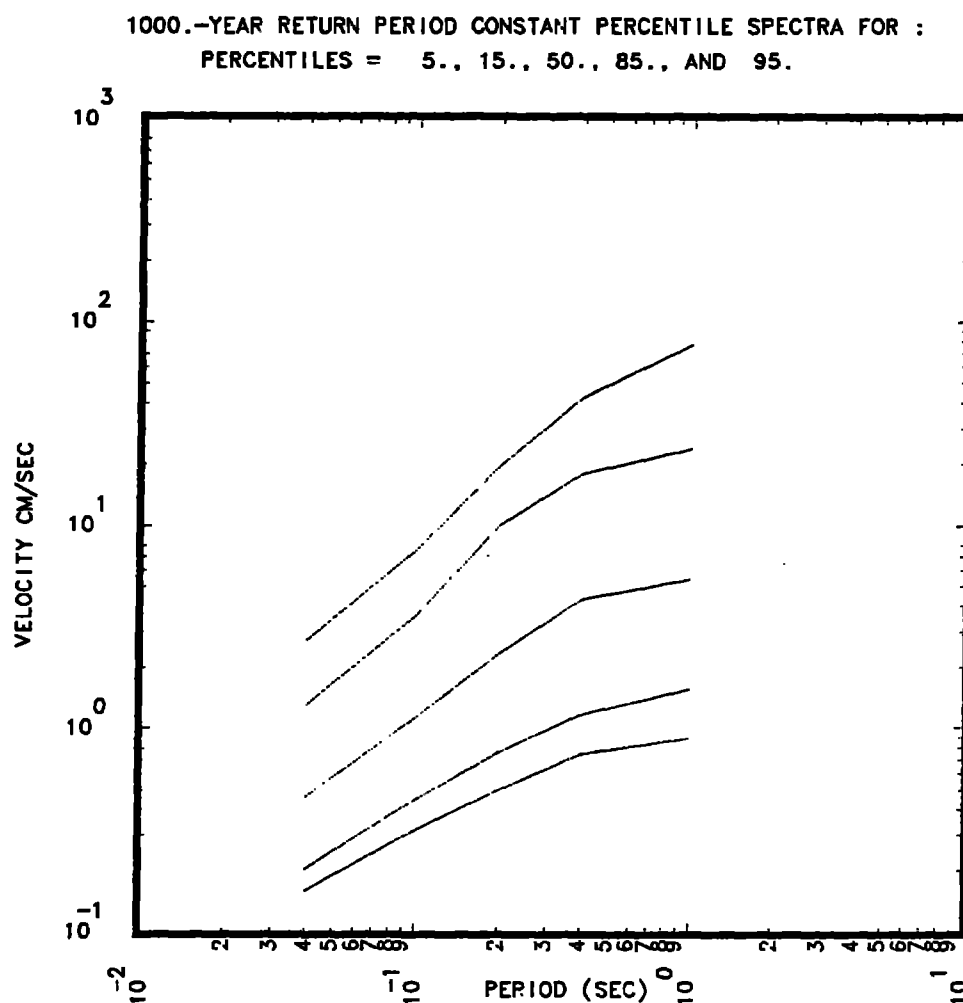
**Fig 50: 85 percent constant percentile hazard curves for the base case (Minimum contributing magnitude = 5.0) of the PSRV at 5 frequencies for the Savannah River site when only four ground motion experts' inputs are used.**



**Fig 51: 95 percent constant percentile hazard curves for the base case (Minimum contributing magnitude = 5.0) of the PSRV at 5 frequencies for the Savannah River site when only four ground motion experts' inputs are used.**

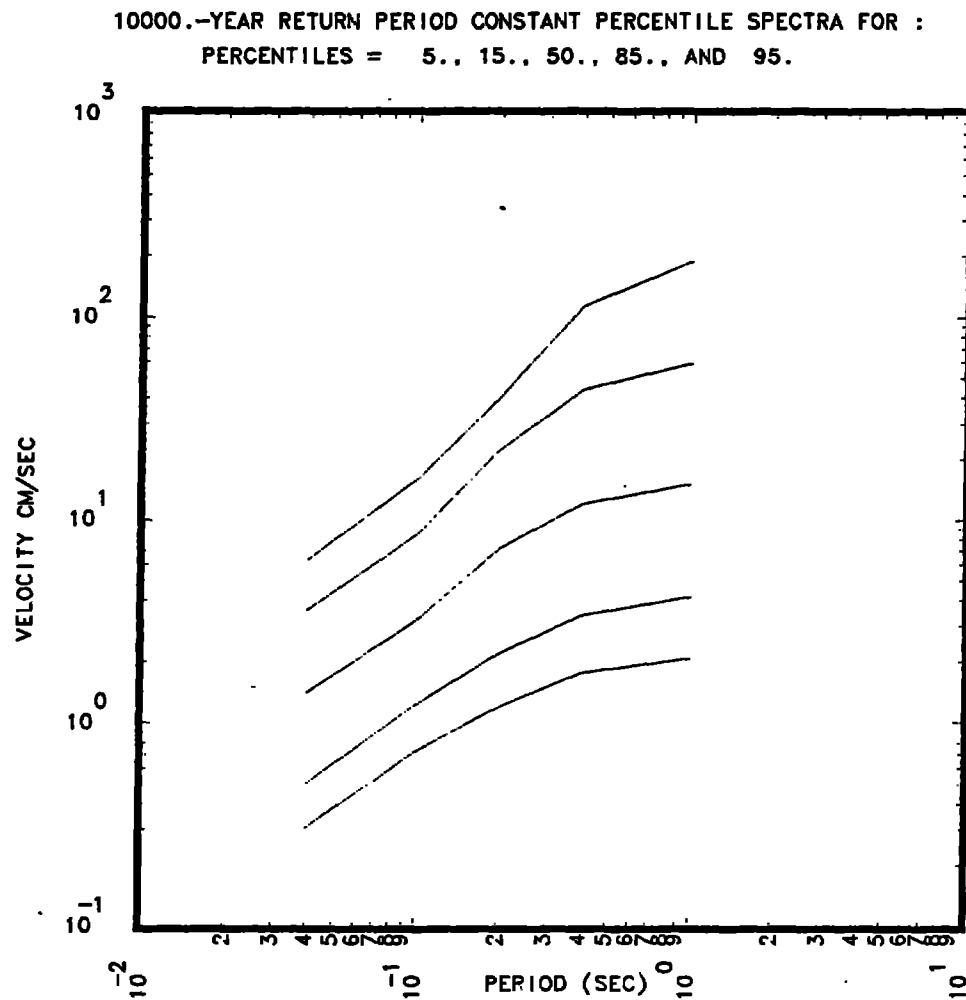


**Fig 52: Arithmetic average Uniform Hazard Spectra for three return periods for the base case (Minimum contributing magnitude = 5.0) for the Savannah River site when only four ground motion experts' inputs are used.**

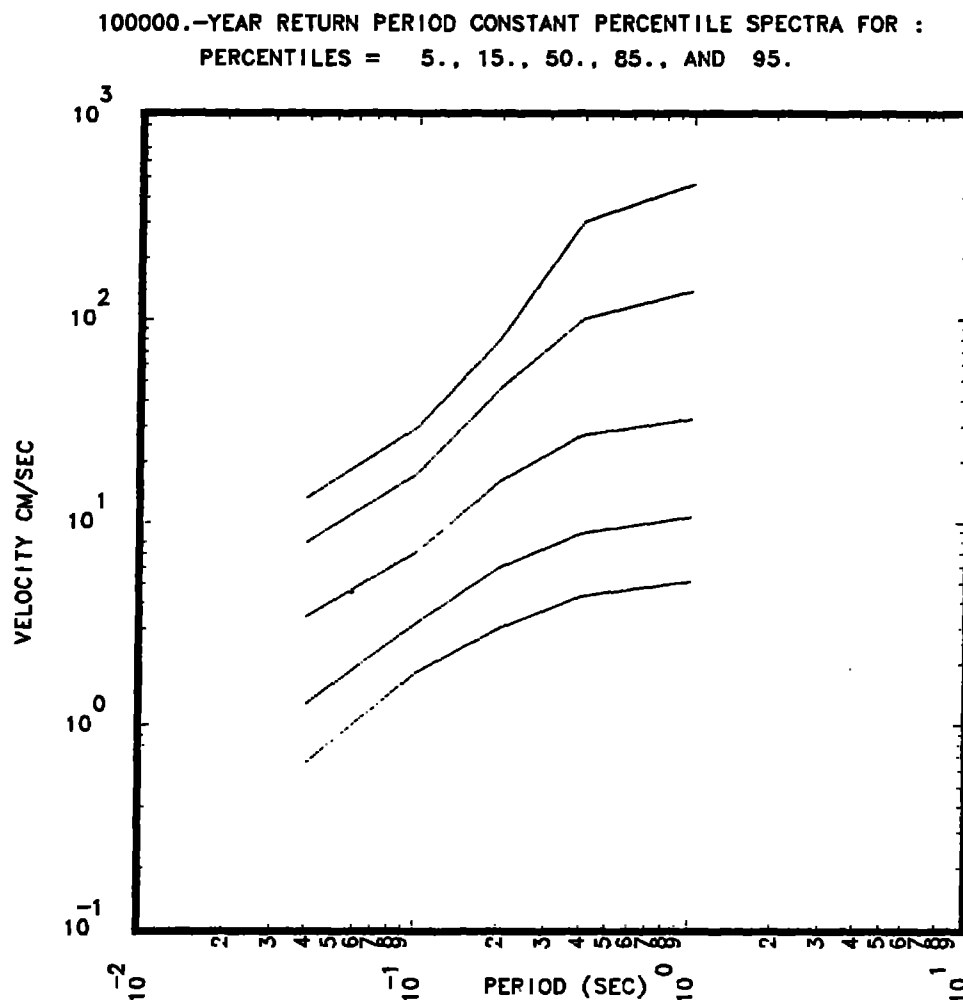


**Fig 53: 5, 15, 50, 85 and 95 percent constant percentile 1000 year return period Uniform Hazard Spectra for the base case (Minimum contributing magnitude = 5.0) for the Savannah River site when only four ground motion experts' inputs are used.**

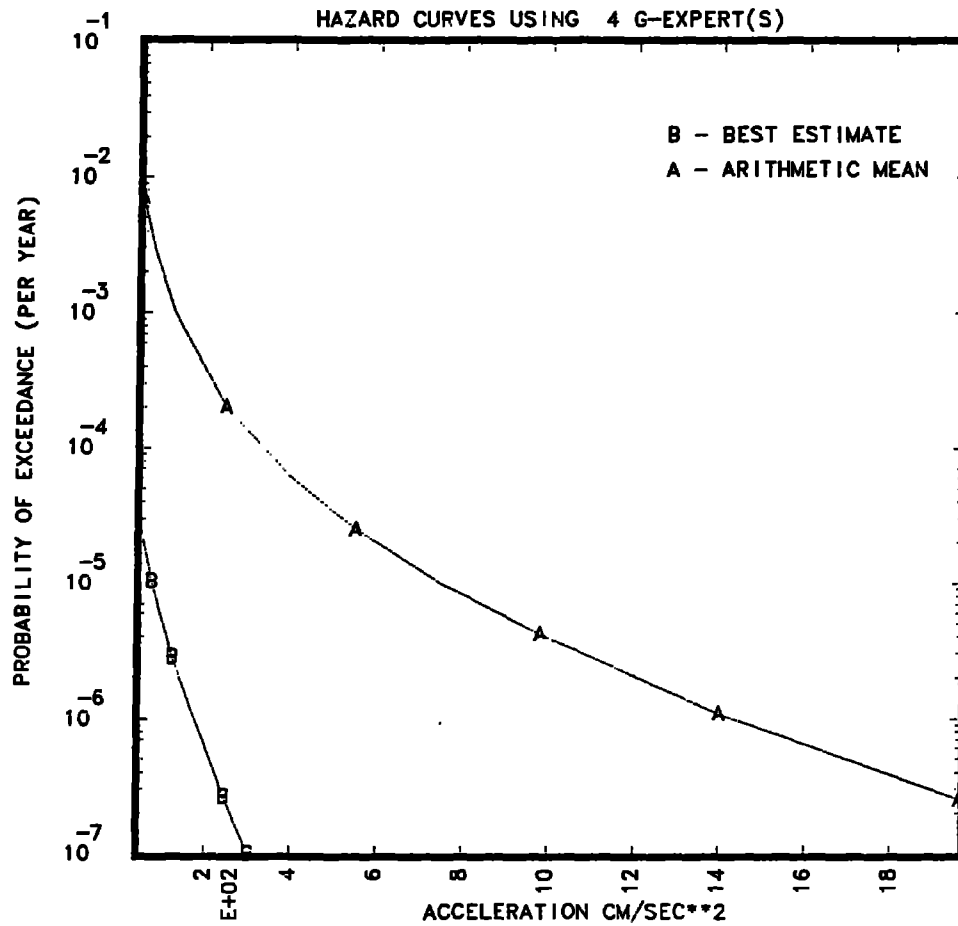




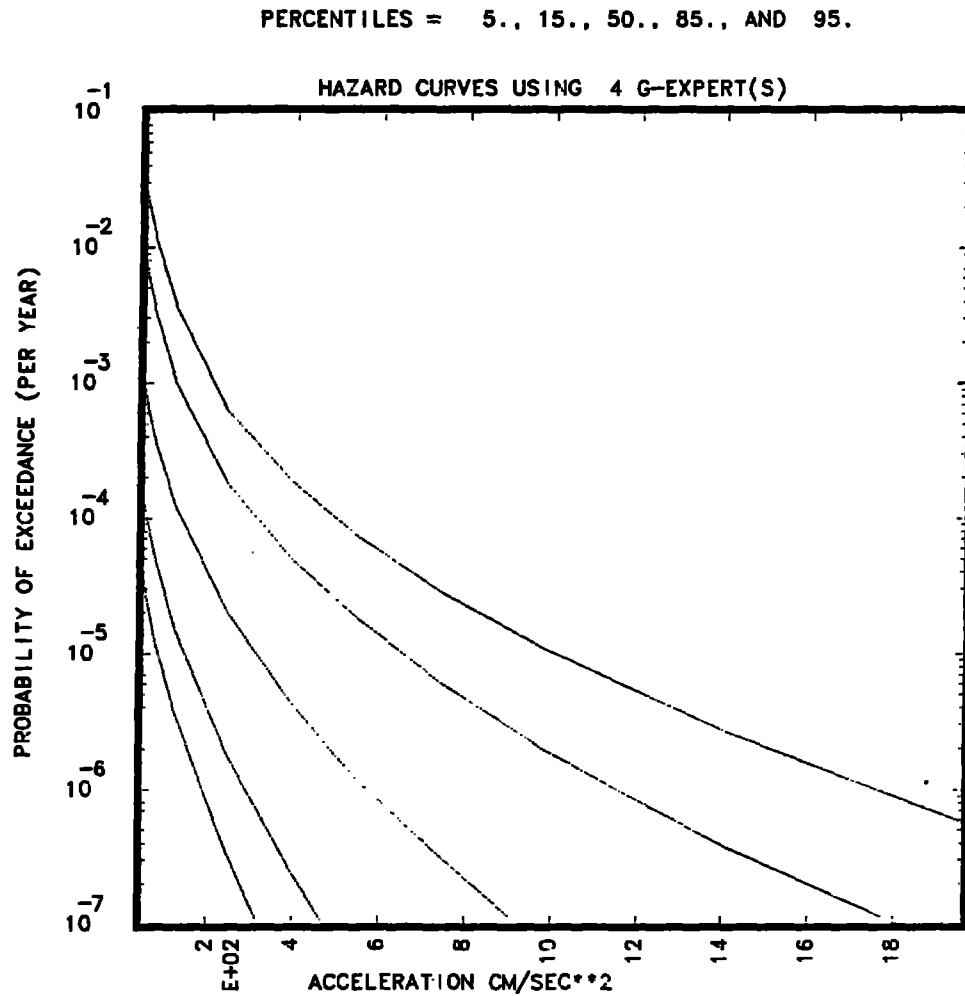
**Fig 54: 5, 15, 50, 85 and 95 percent constant percentile 10,000 year return period Uniform Hazard Spectra for the base case (Minimum contributing magnitude = 5.0) for the Savannah River site when only four ground motion experts' inputs are used.**



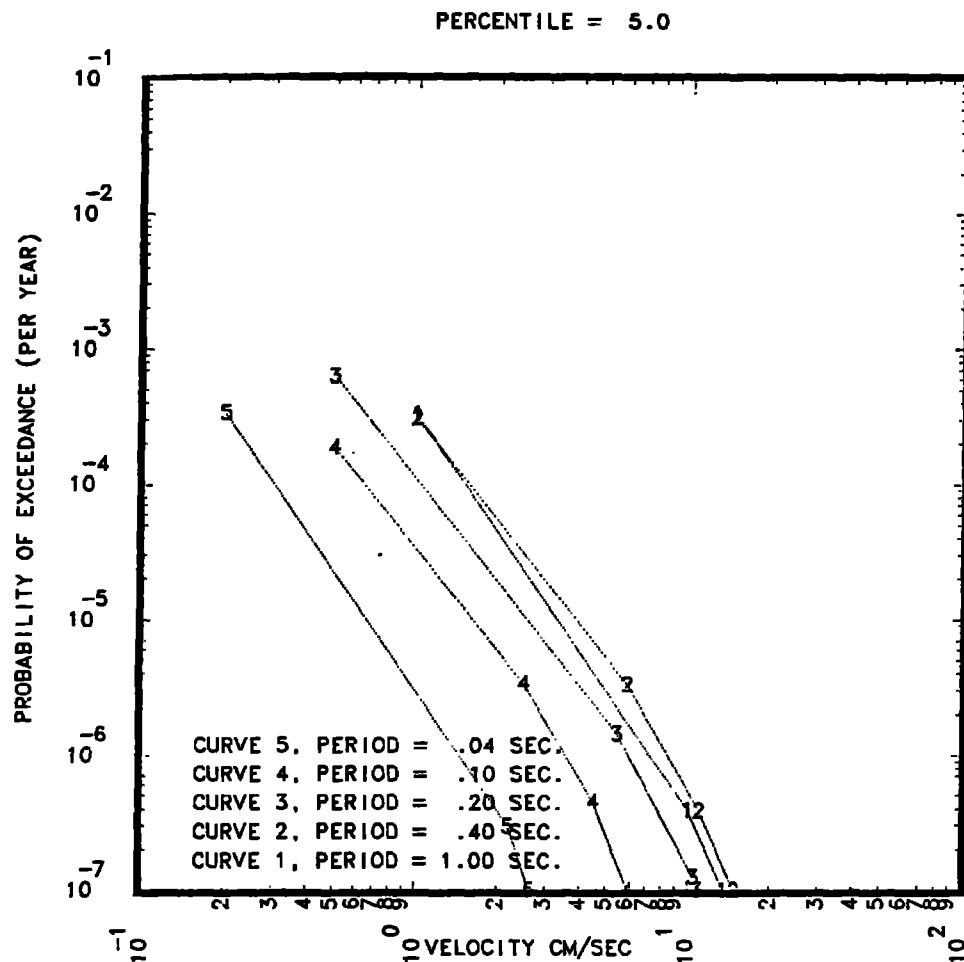
**Fig 55: 5, 15, 50, 85 and 95 percent constant percentile 100,000 year return period Uniform Hazard Spectra for the base case (Minimum contributing magnitude = 5.0) for the Savannah River Site when only four ground motion experts' inputs are used.**



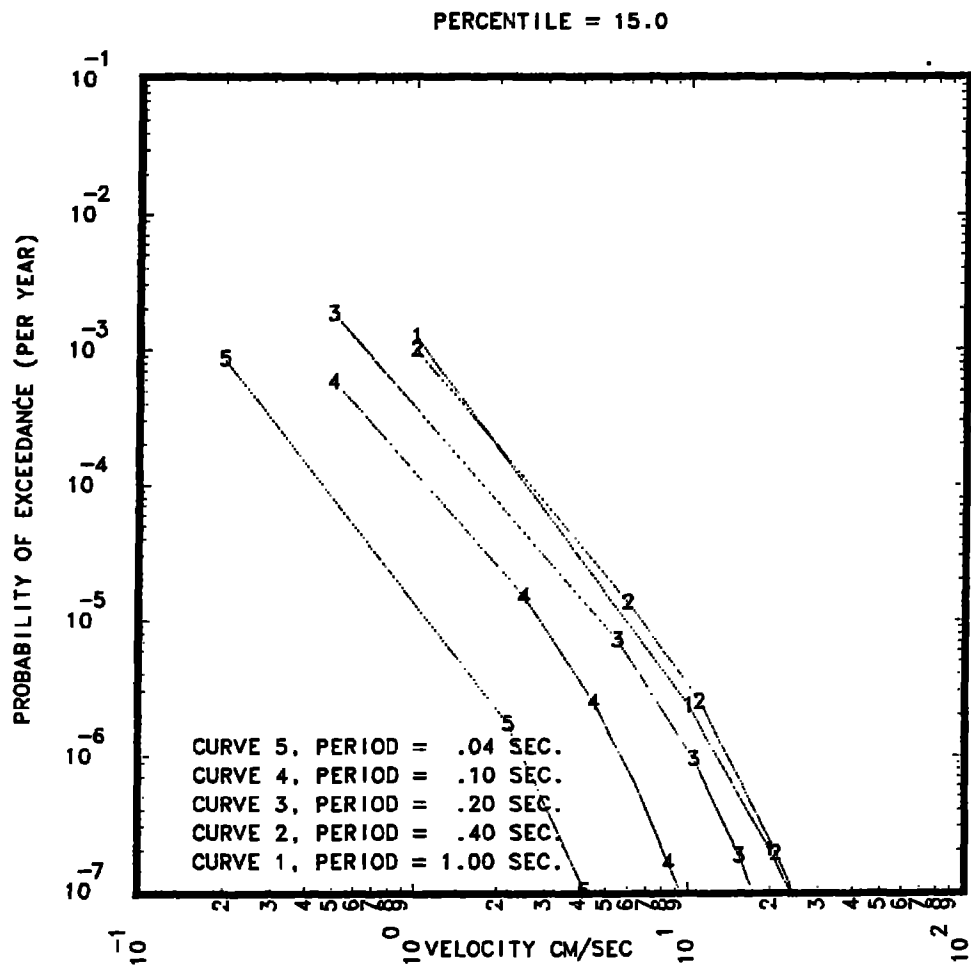
**Fig 56: Best estimate and arithmetic average hazard curves for the Case 2 (only earthquakes with magnitudes between 5 and 6 contribute to the hazard) of the PGA for the Savannah River site when only four ground motion experts' inputs are used.**



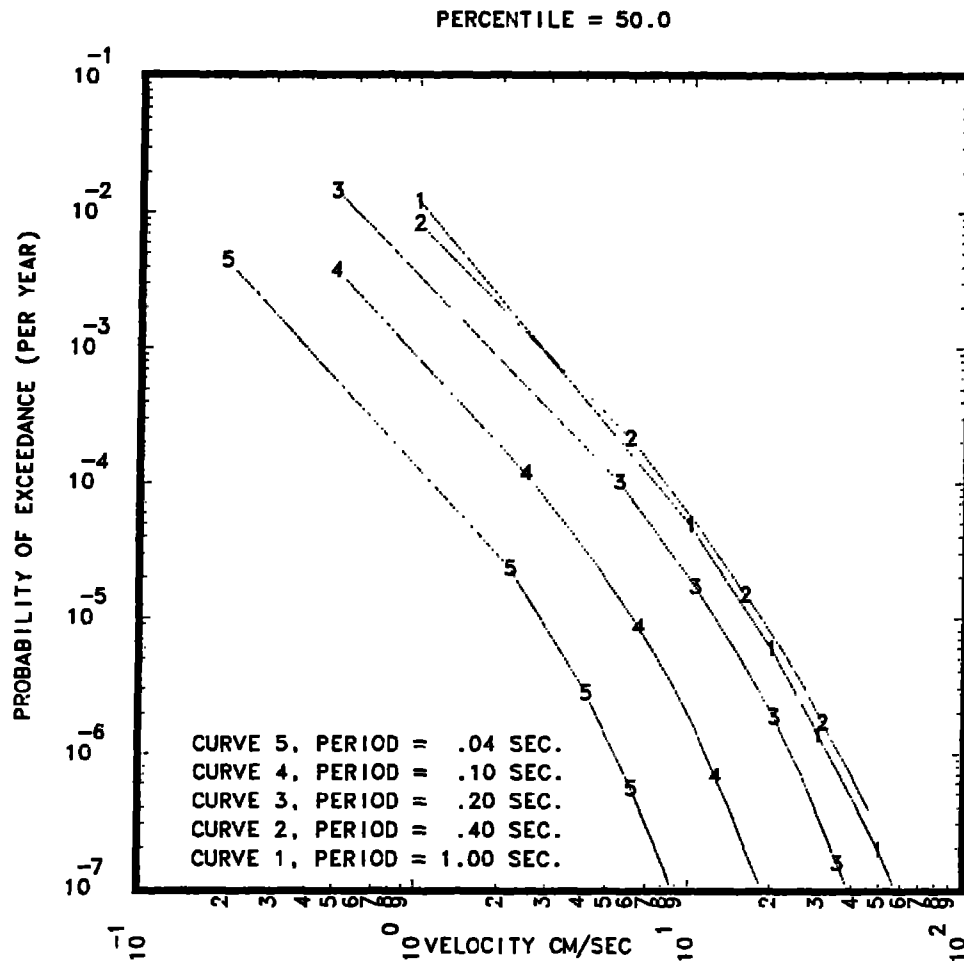
**Fig 57: 5, 15, 50, 85, and 95 percent constant percentile hazard curves for the Case 2 (only earthquakes with magnitudes between 5 and 6 contribute to the hazard) of the PGA for the Savannah River site when only four ground motion experts' inputs are used.**



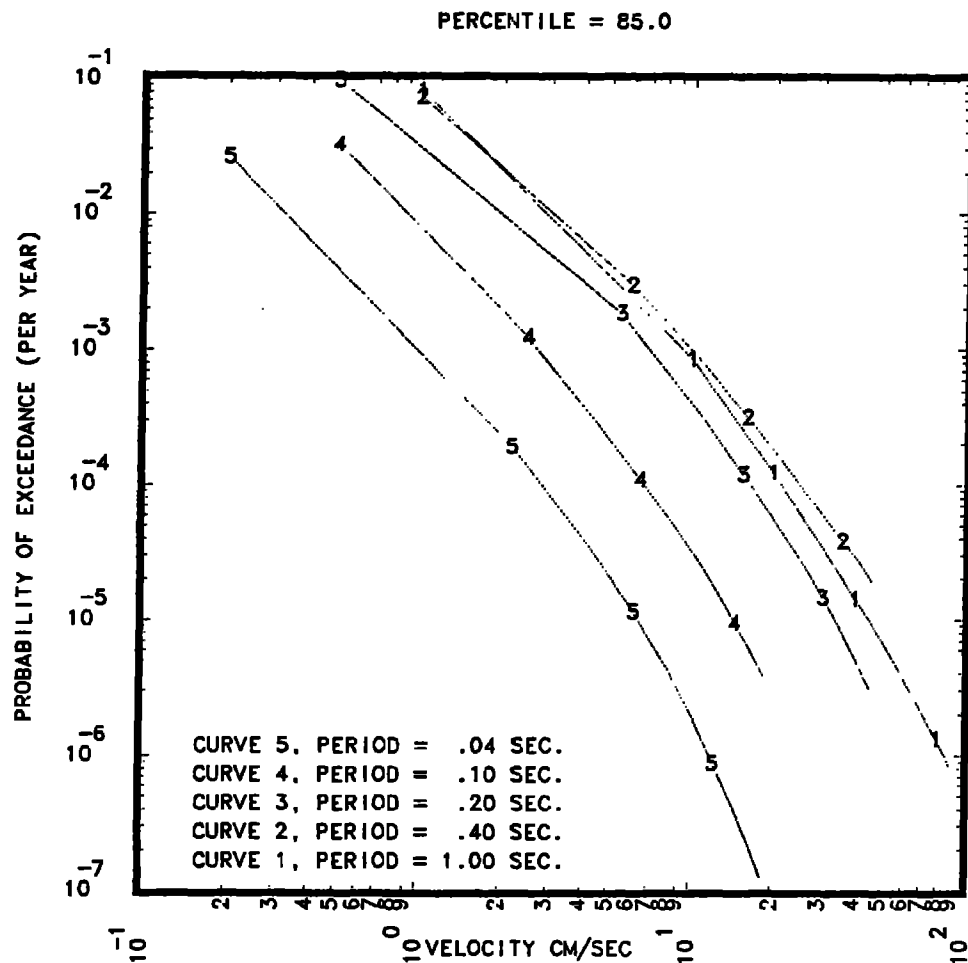
**Fig 58: 5 percent constant percentile hazard curves for the Case 2 (only earthquakes with magnitudes between 5 and 6 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site when only four ground motion experts' inputs are used.**



**Fig 59: 15 percent constant percentile hazard curves for the Case 2 (only earthquakes with magnitudes between 5 and 6 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site when only four ground motion experts' inputs are used.**

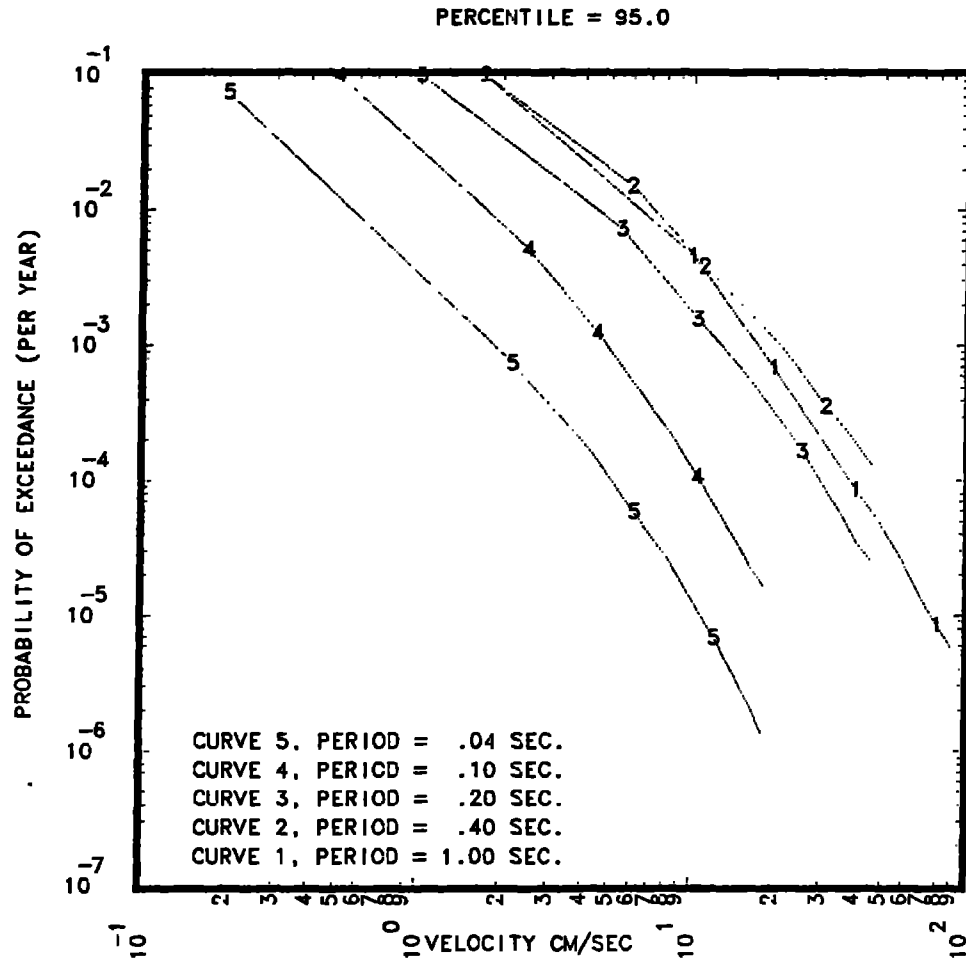


**Fig 60: 50 percent constant percentile hazard curves for the Case 2 (only earthquakes with magnitudes between 5 and 6 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site when only four ground motion experts' inputs are used.**

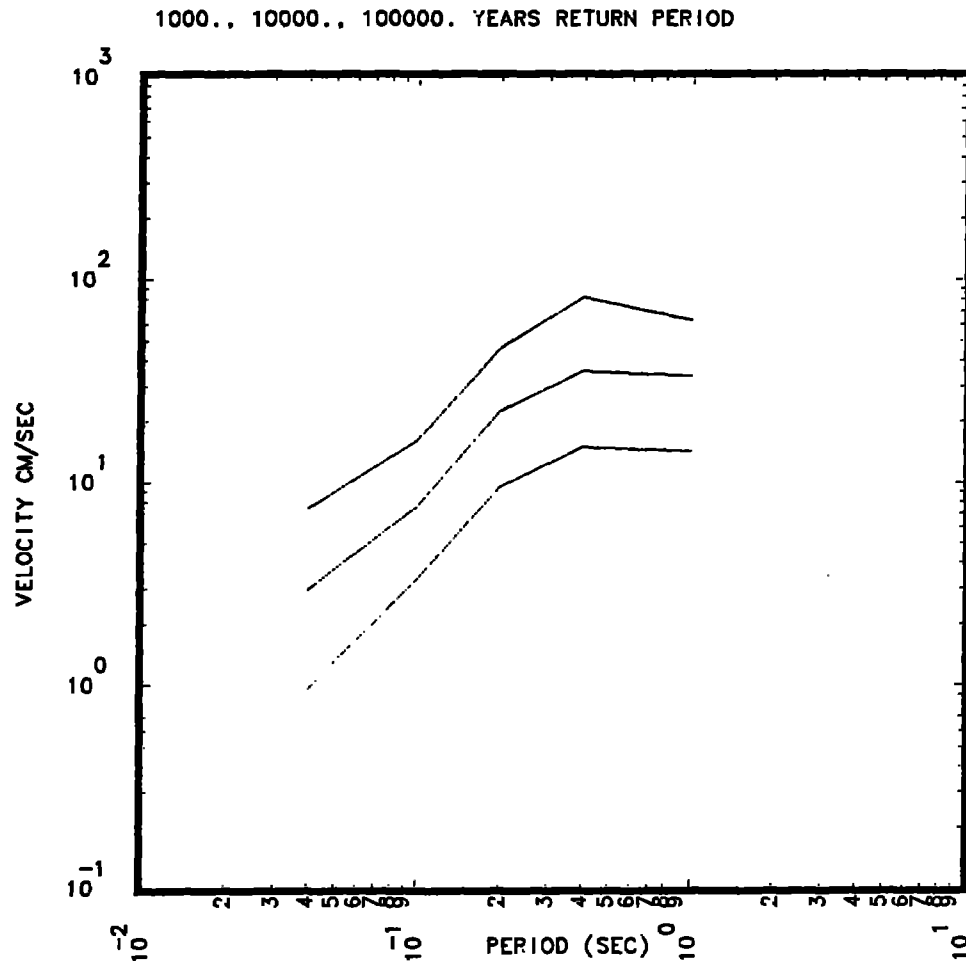


**Fig 61: 85 percent constant percentile hazard curves for the Case 2 (only earthquakes with magnitudes between 5 and 6 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site when only four ground motion experts' inputs are used.**

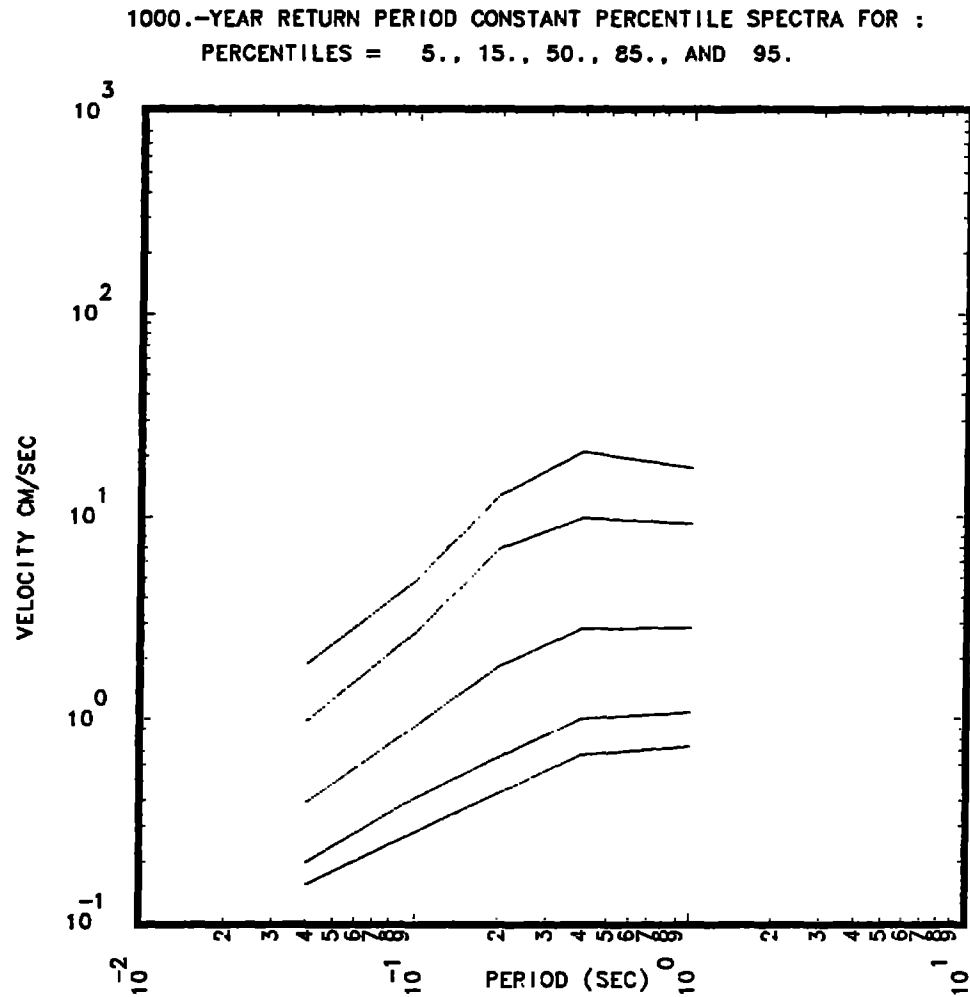




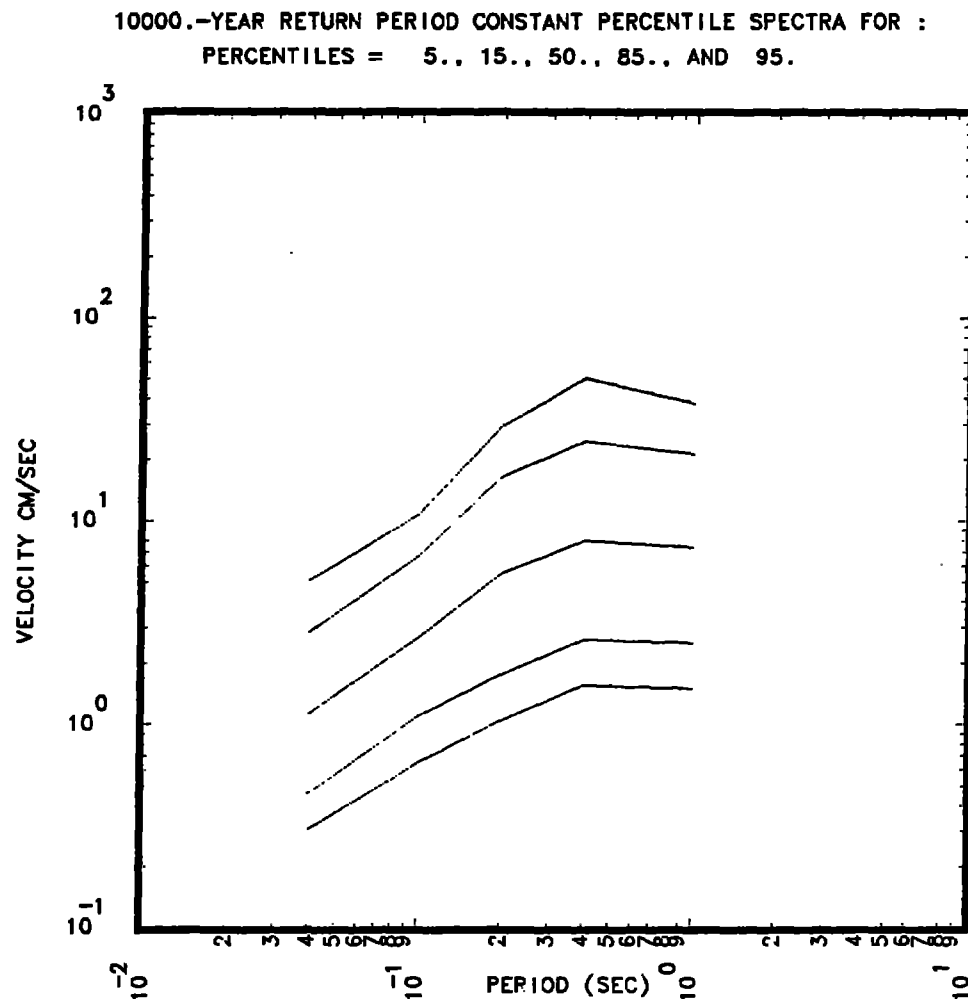
**Fig 62: 95 percent constant percentile hazard curves for the Case 2 (only earthquakes with magnitudes between 5 and 6 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site when only four ground motion experts' inputs are used.**



**Fig 63: Arithmetic average Uniform Hazard Spectra for three return periods for the Case 2 (only earthquakes with magnitudes between 5 and 6 contribute to the hazard) for the Savannah River site when only four ground motion experts' inputs are used.**

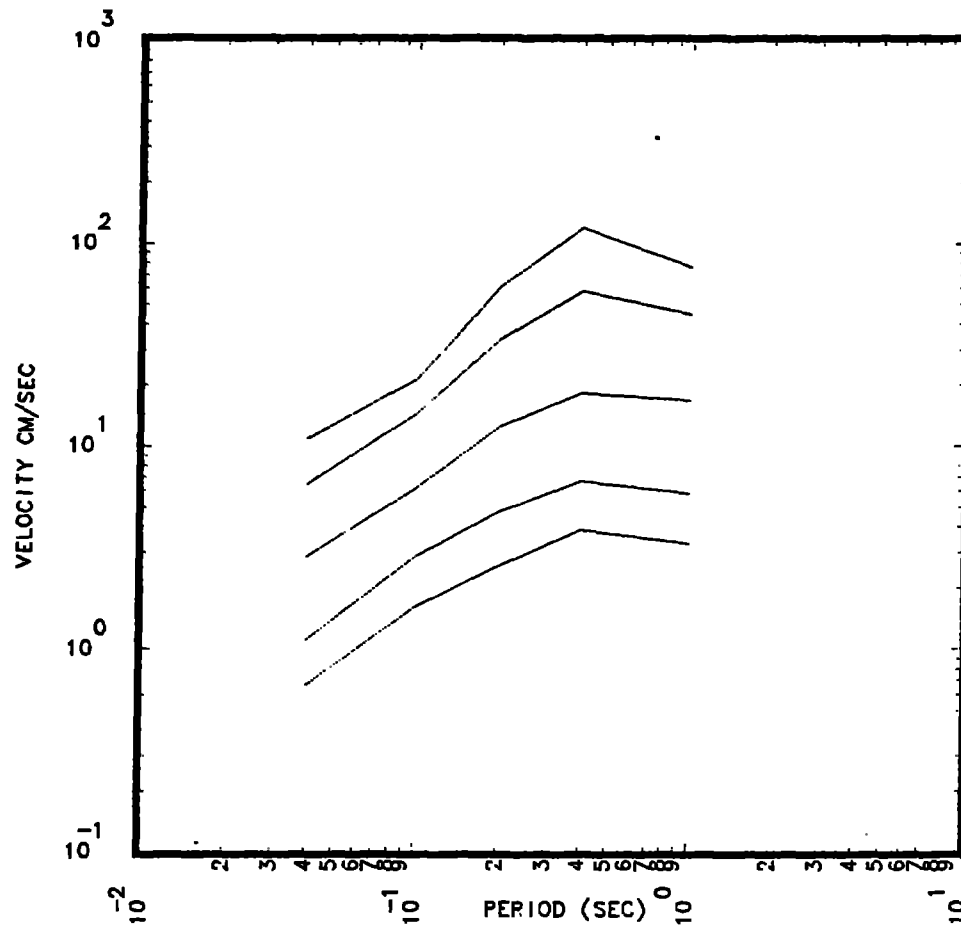


**Fig 64: 5, 15, 50, 85 and 95 percent constant percentile 1000 year return period Uniform Hazard Spectra for the Case 2 (only earthquakes with magnitudes between 5 and 6 contribute to the hazard) for the Savannah River site when only four ground motion experts' inputs are used.**

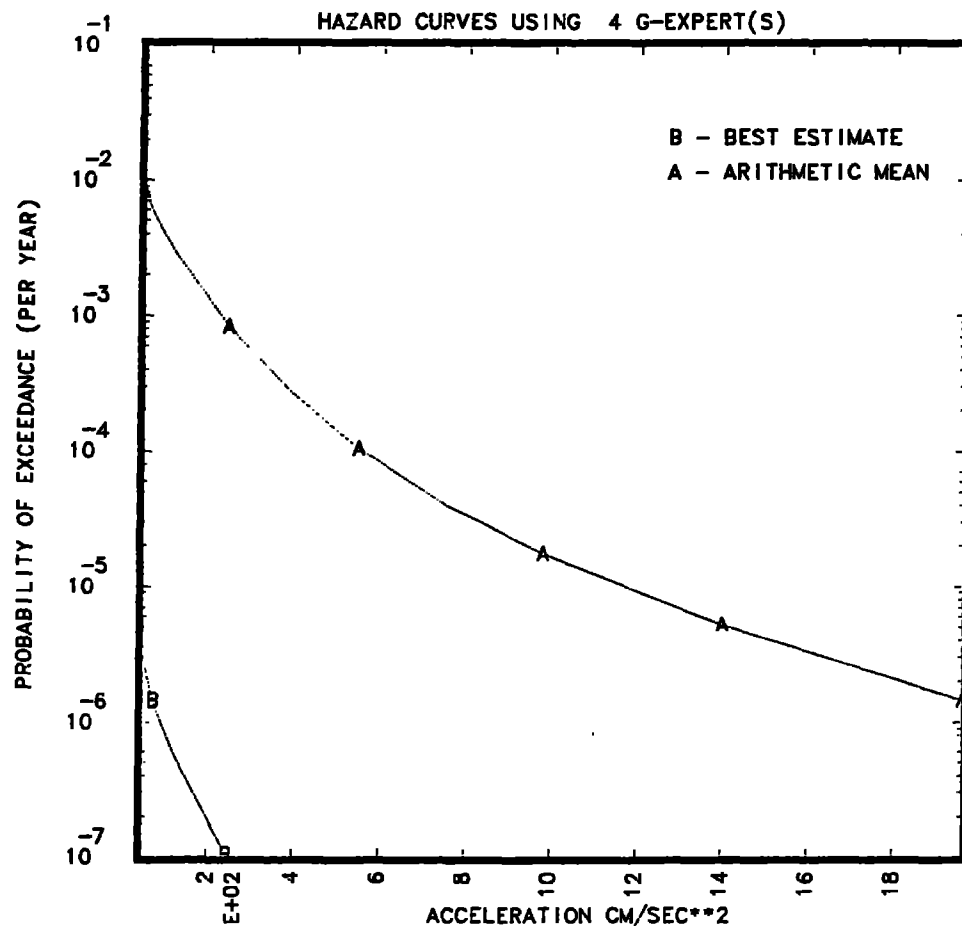


**Fig 65: 5, 15, 50, 85 and 95 percent constant percentile 10,000 year return period Uniform Hazard Spectra for the Case 2 (only earthquakes with magnitudes between 5 and 6 contribute to the hazard) for the Savannah River site when only four ground motion experts' inputs are used.**

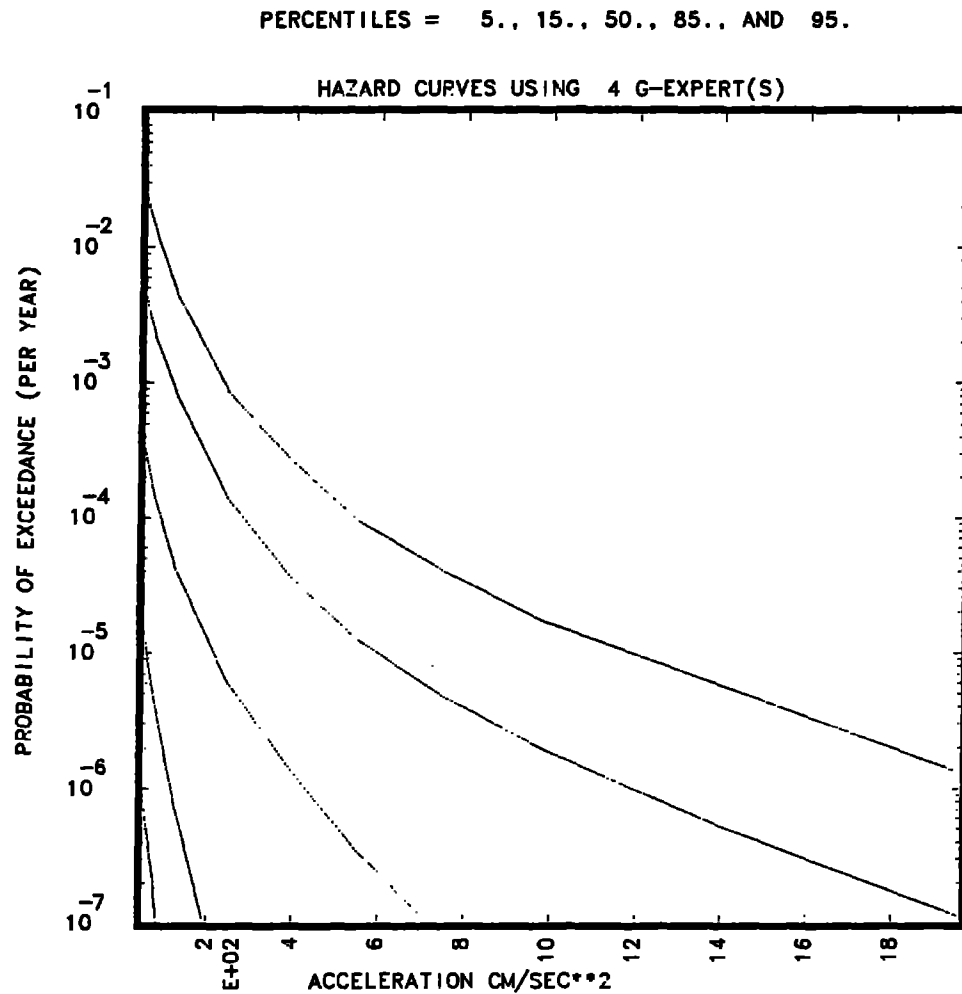
100000.-YEAR RETURN PERIOD CONSTANT PERCENTILE SPECTRA FOR :  
 PERCENTILES = 5., 15., 50., 85., AND 95.



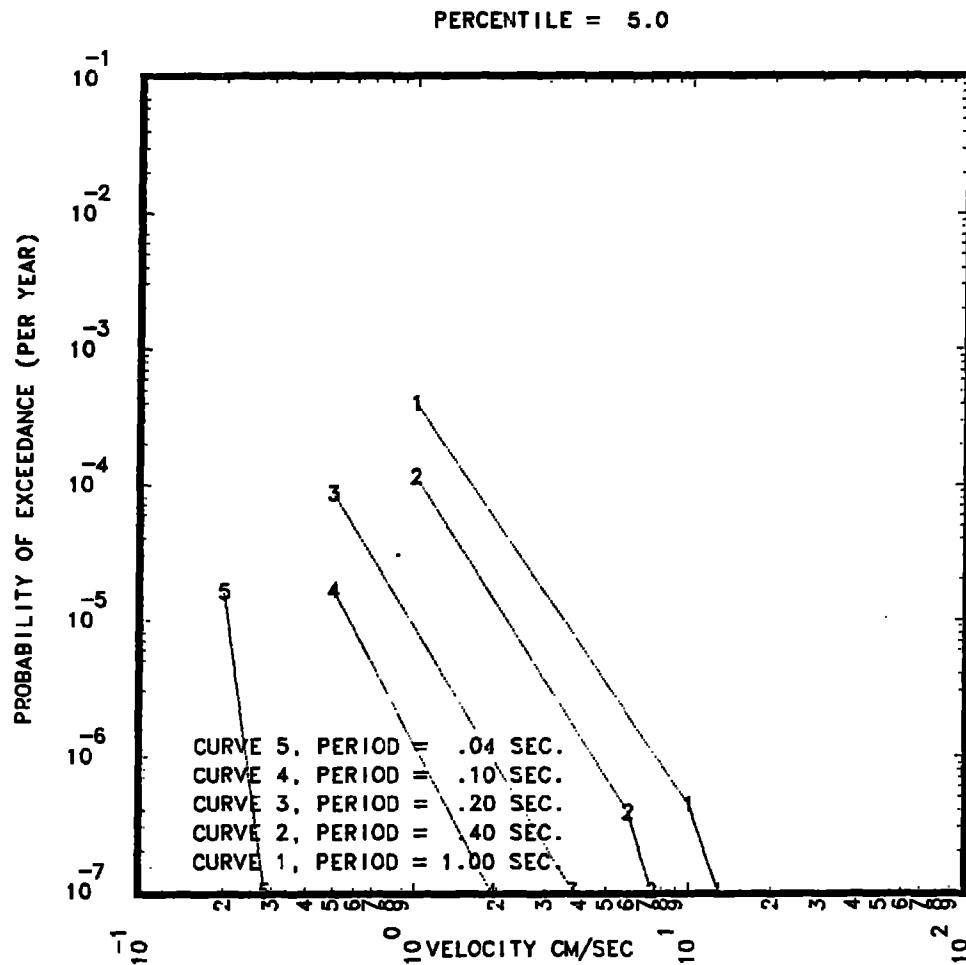
**Fig 66: 5, 15, 50, 85 and 95 percent constant percentile 100,000 year return period Uniform Hazard Spectra for the Case 2 (only earthquakes with magnitudes between 5 and 6 contribute to the hazard) for the Savannah River site when only four ground motion experts' inputs are used.**



**Fig 67: Best estimate and arithmetic average hazard curves for the Case 3 (only earthquakes greater than magnitude 6.0 contribute to the hazard) of the PGA for the Savannah River site when only four ground motion experts' inputs are used.**

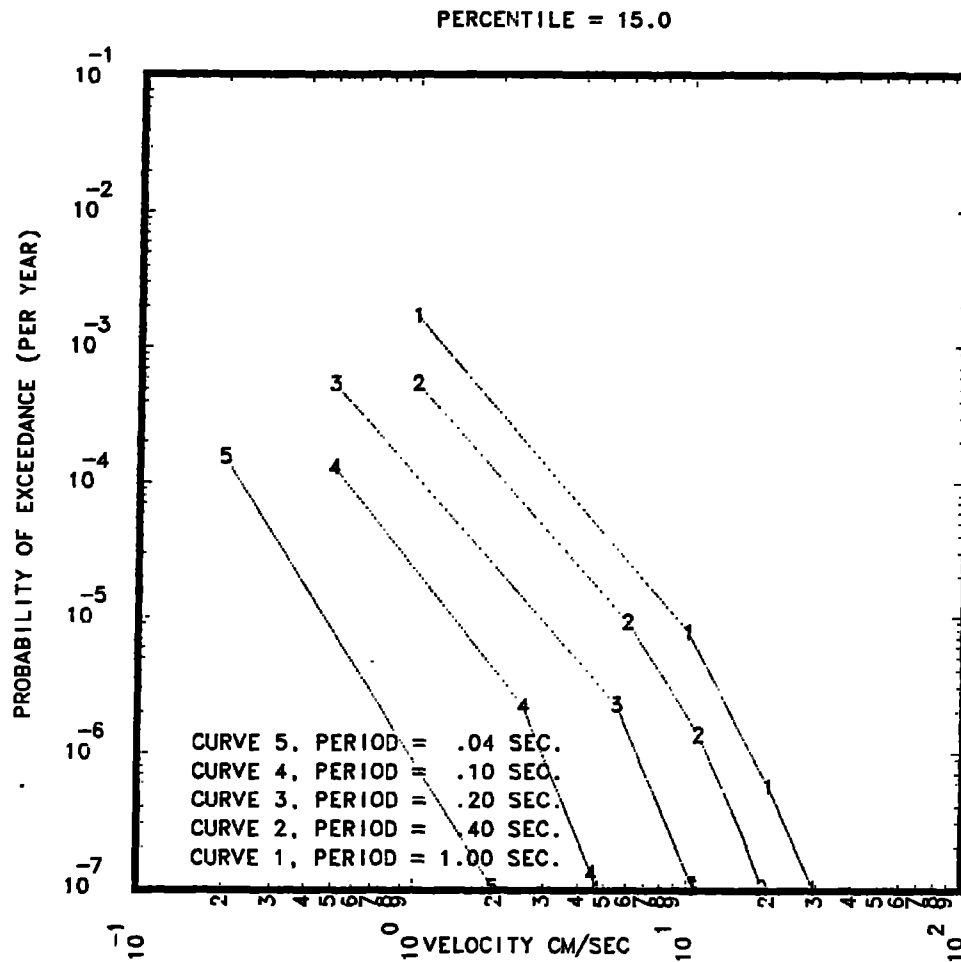


**Fig 68: 5, 15, 50, 85, and 95 percent constant percentile hazard curves for the Case 3 (only earthquakes greater than magnitude 6.0 contribute to the hazard) of the PGA for the Savannah River site when only four ground motion experts' inputs are used.**

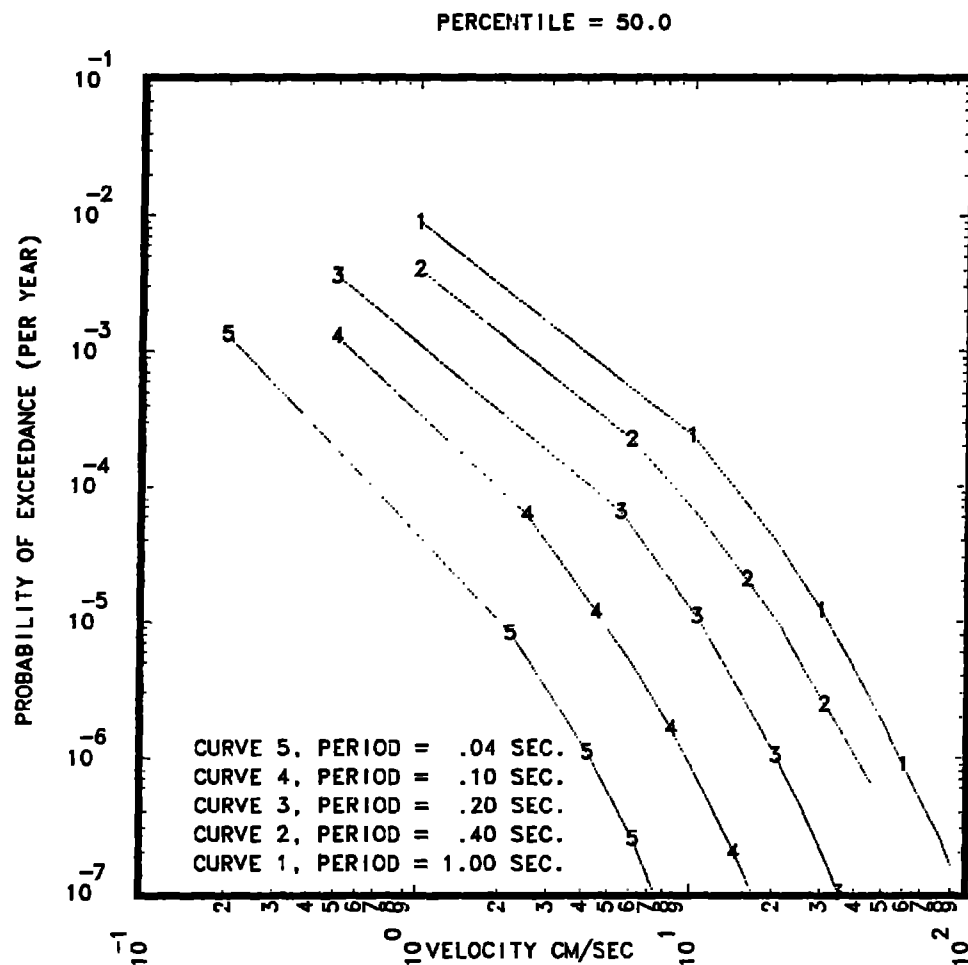


**Fig 69: 5 percent constant percentile hazard curves for the Case 3 (only earthquakes greater than magnitude 6.0 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site when only four ground motion experts' inputs are used.**

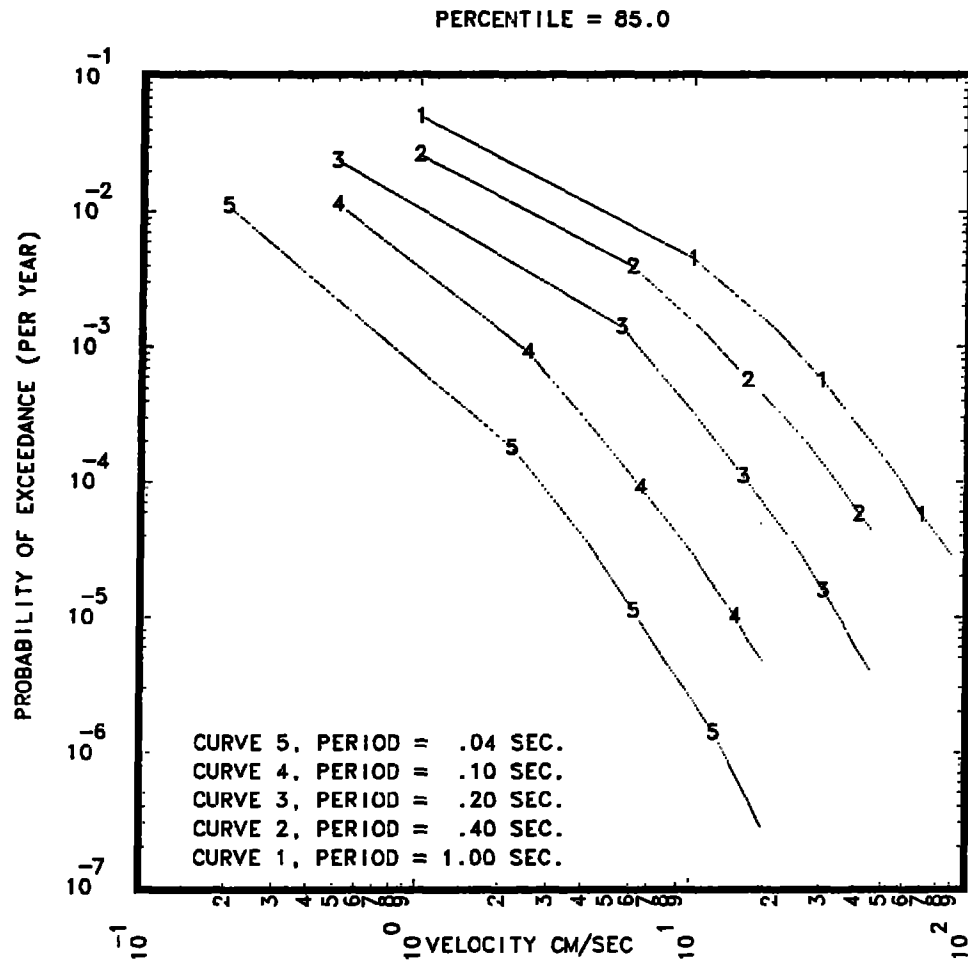




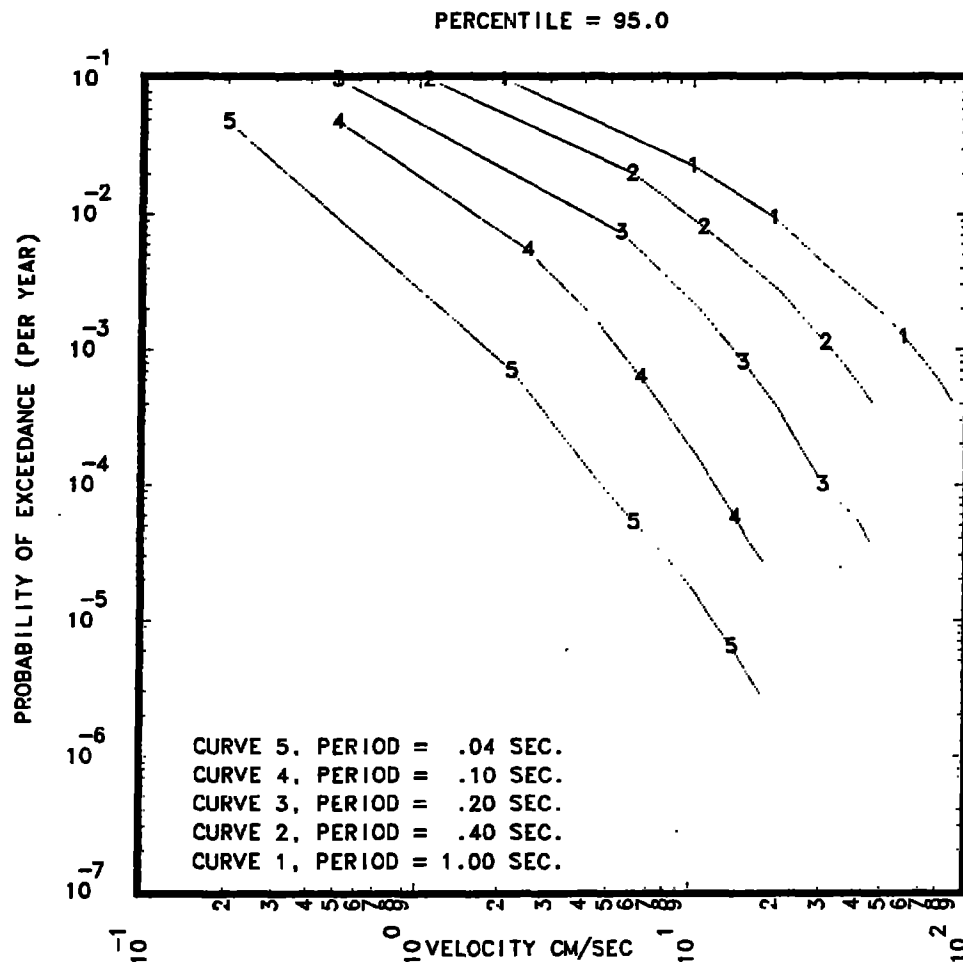
**Fig 70: 15 percent constant percentile hazard curves for the Case 3 (only earthquakes greater than magnitude 6.0 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site when only four ground motion experts' inputs are used.**



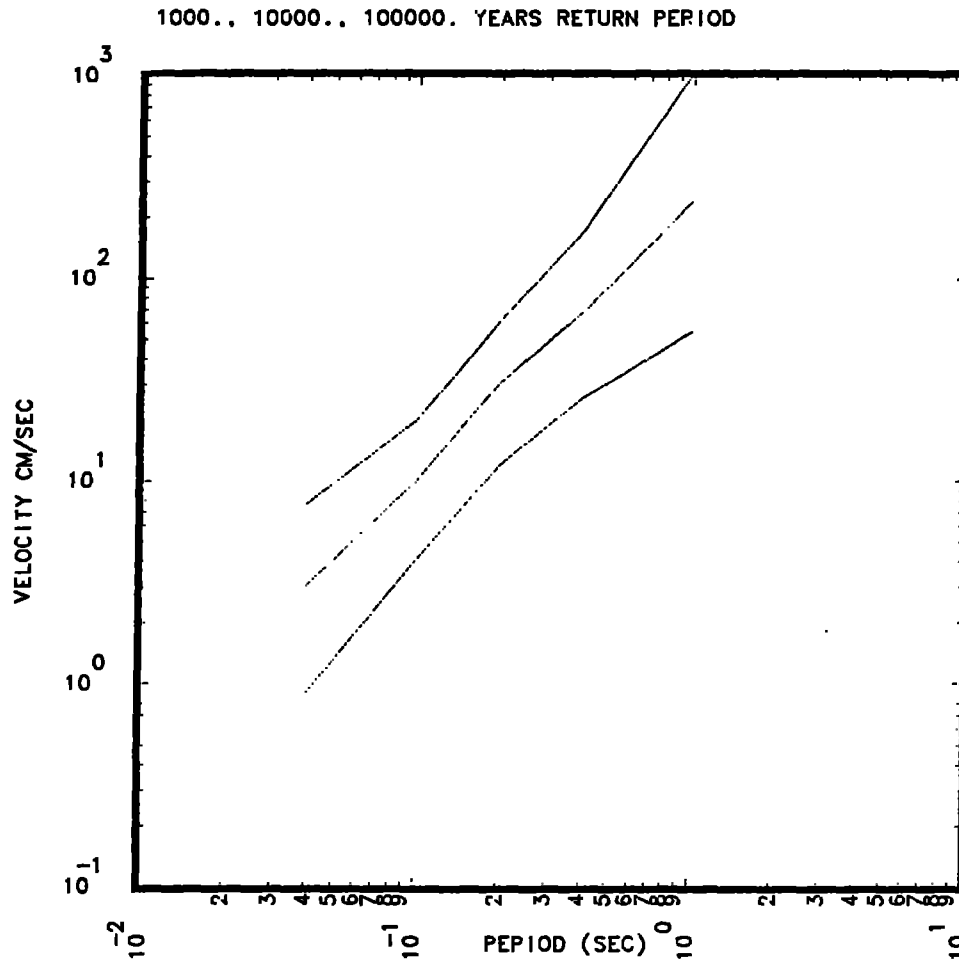
**Fig 71: 50 percent constant percentile hazard curves for the Case 3 (only earthquakes greater than magnitude 6.0 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site when only four ground motion experts' inputs are used.**



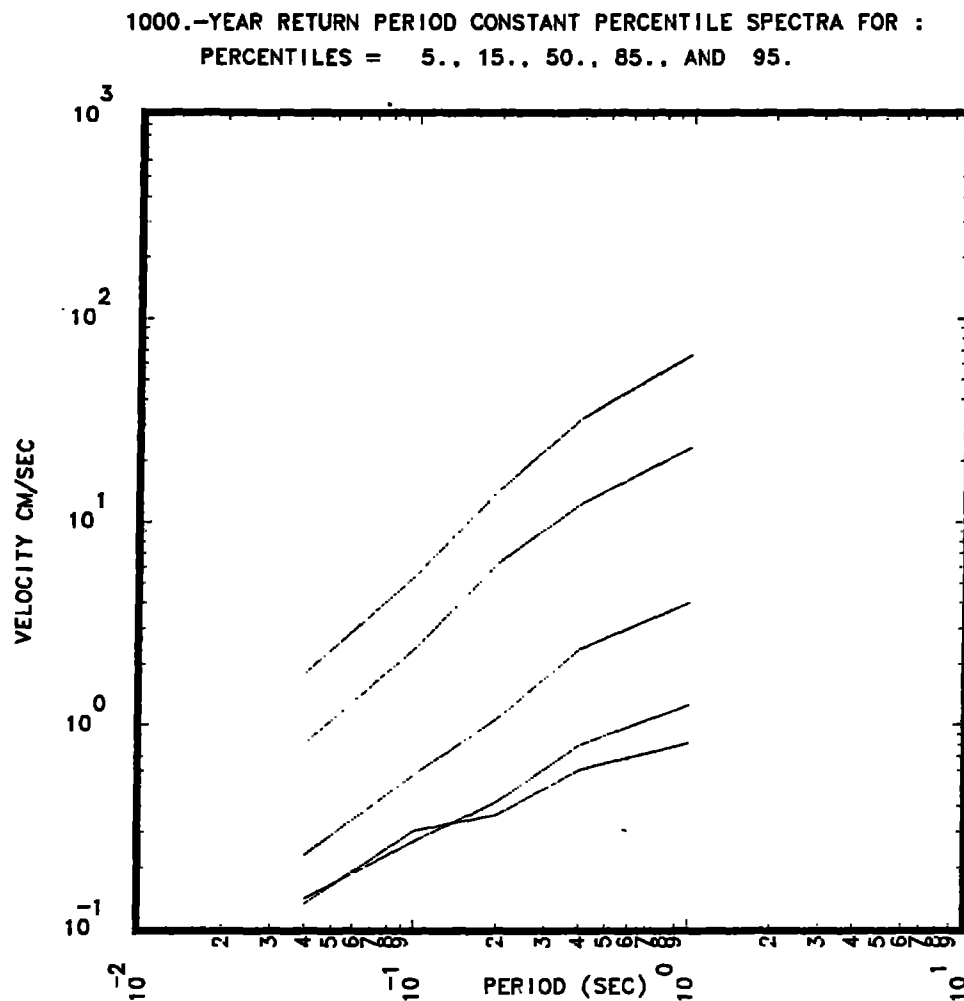
**Fig 72: 85 percent constant percentile hazard curves for the Case 3 (only earthquakes greater than magnitude 6.0 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site when only four ground motion experts' inputs are used.**



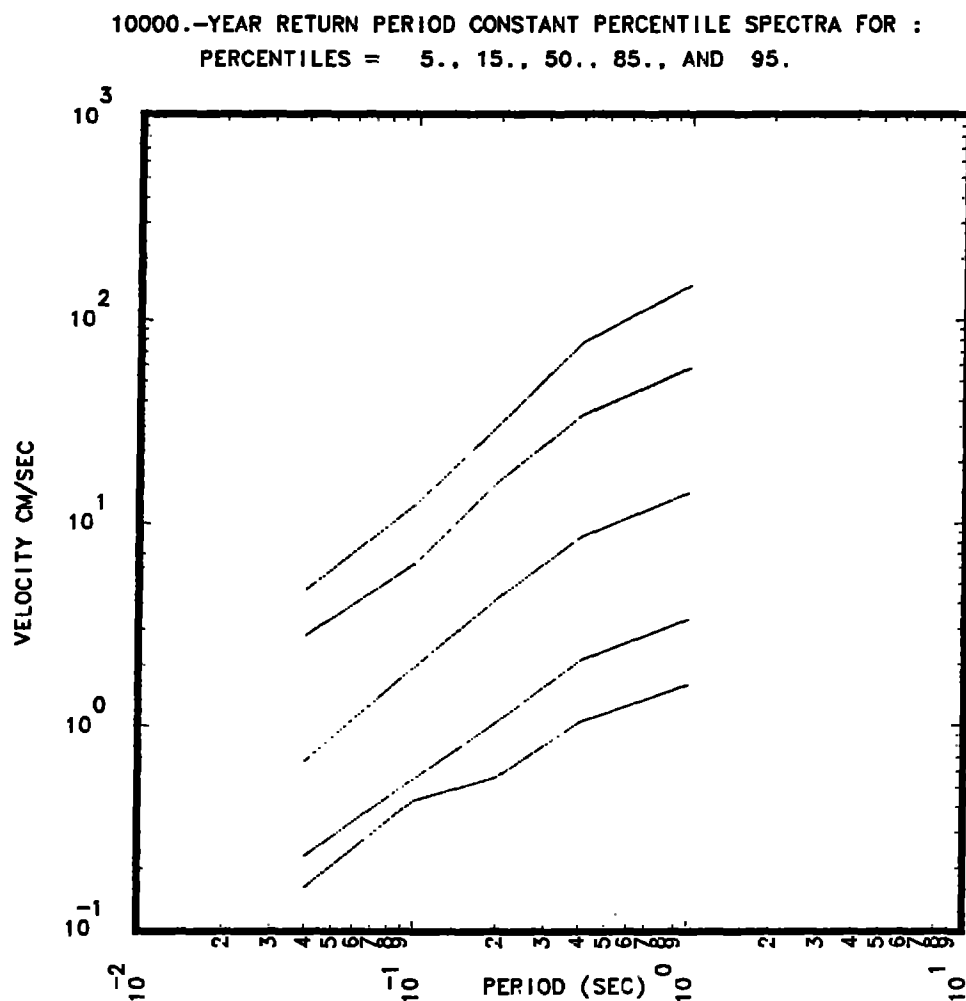
**Fig 73: 95 percent constant percentile hazard curves for the Case 3 (only earthquakes greater than magnitude 6.0 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site when only four ground motion experts' inputs are used.**



**Fig 74:** Arithmetic average Uniform Hazard Spectra for three return periods for the Case 3 (only earthquakes greater than magnitude 6.0 contribute to the hazard) for the Savannah River site when only four ground motion experts' inputs are used.

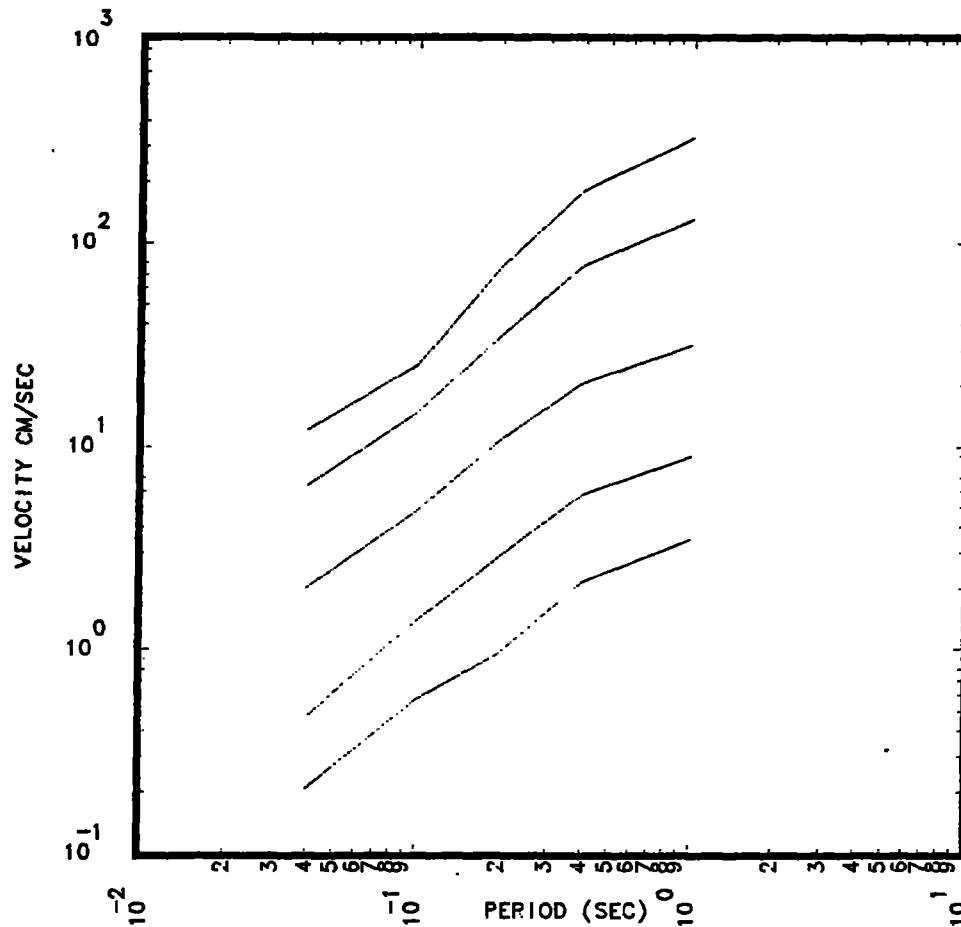


**Fig 75: 5, 15, 50, 85 and 95 percent constant percentile 1000 year return period Uniform Hazard Spectra for the Case 3 (only earthquakes greater than magnitude 6.0 contribute to the hazard) for the Savannah River site when only four ground motion experts' inputs are used.**



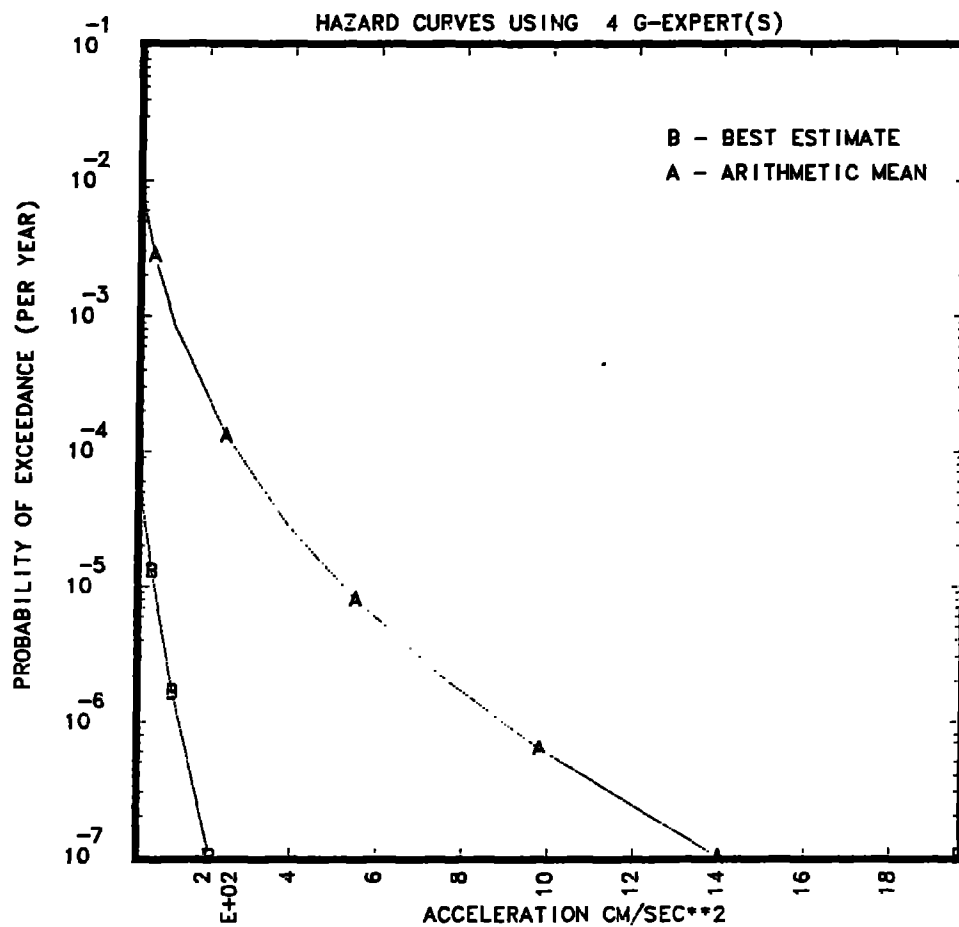
**Fig 76: 5, 15, 50, 85 and 95 percent constant percentile 10,000 year return period Uniform Hazard Spectra for the Case 3 (only earthquakes greater than magnitude 6.0 contribute to the hazard) for the Savannah River site when only four ground motion experts' inputs are used.**

100000.-YEAR RETURN PERIOD CONSTANT PERCENTILE SPECTRA FOR :  
 PERCENTILES = 5., 15., 50., 85., AND 95.

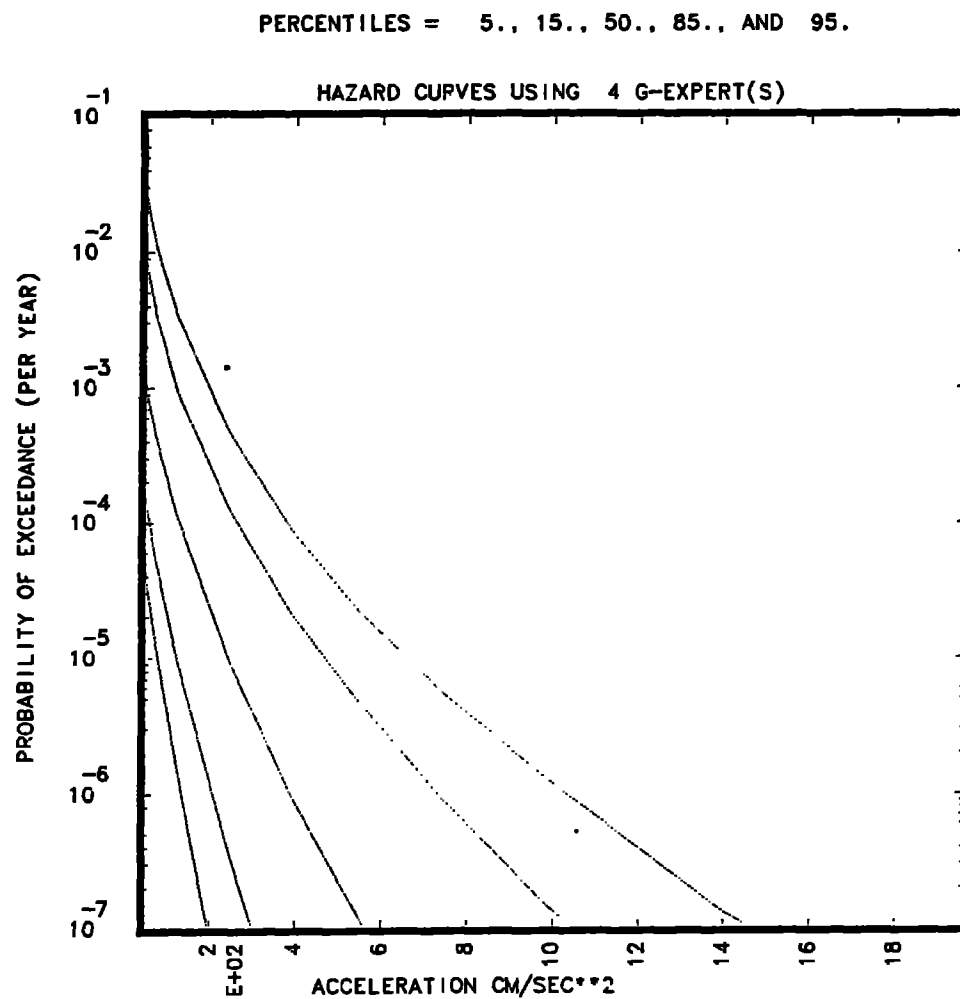


**Fig 77: 5, 15, 50, 85 and 95 percent constant percentile 100,000 year return period Uniform Hazard Spectra for the Case 3 (only earthquakes greater than magnitude 6.0 contribute to the hazard) for the Savannah River site when only four ground motion experts' inputs are used.**

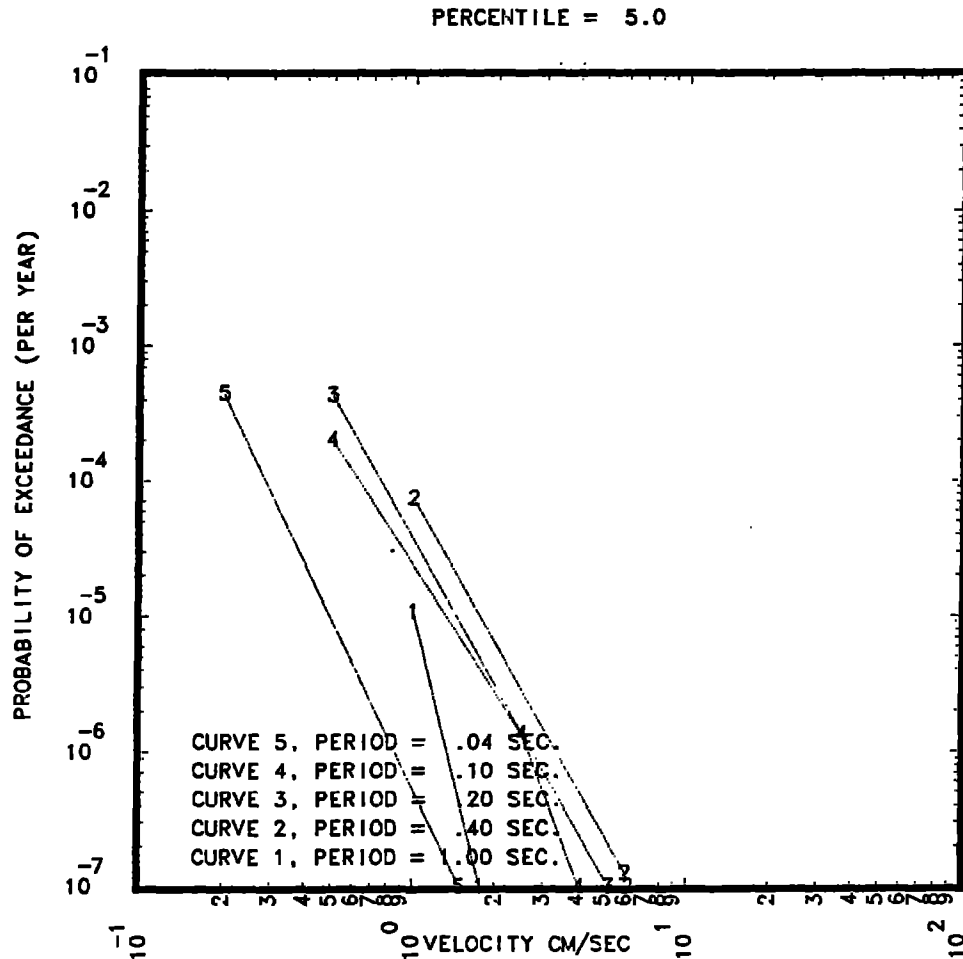




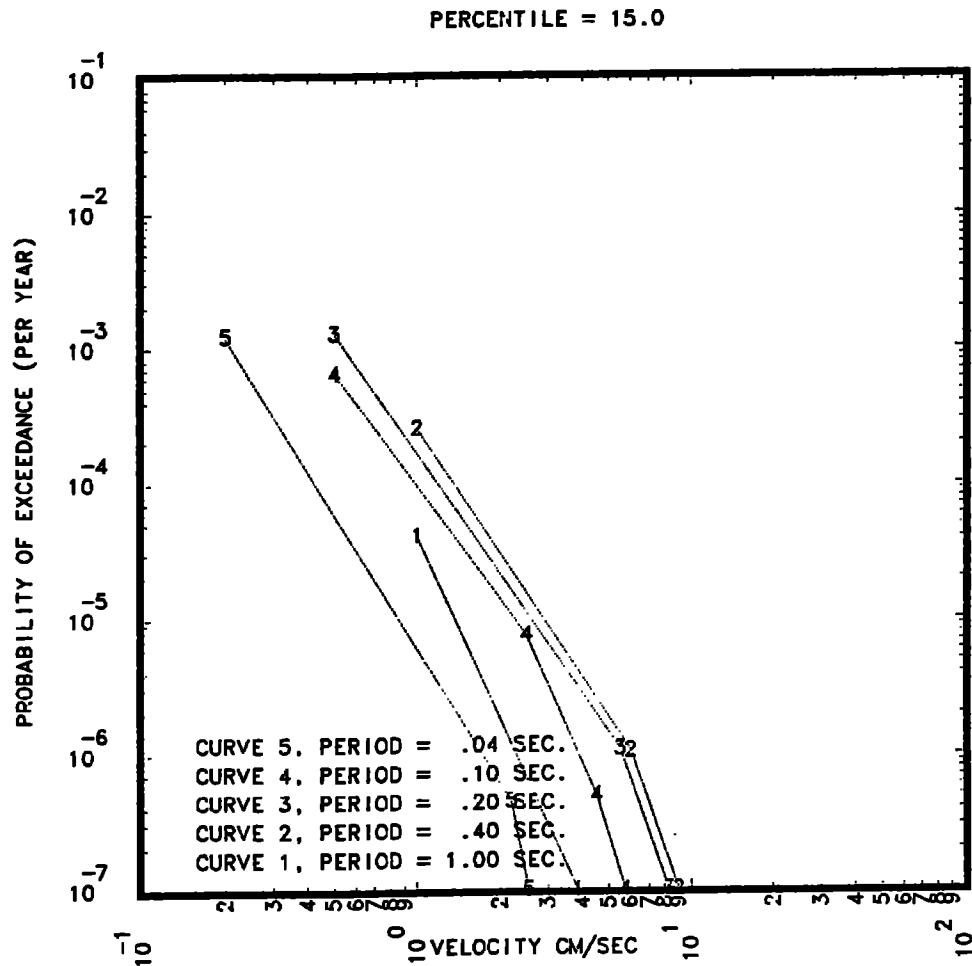
**Fig 78: Best estimate and arithmetic average hazard curves for the Case 4 (only earthquakes with magnitudes between 4.0 and 5.0 contribute to the hazard) of the PGA for the Savannah River site when only four ground motion experts' inputs are used.**



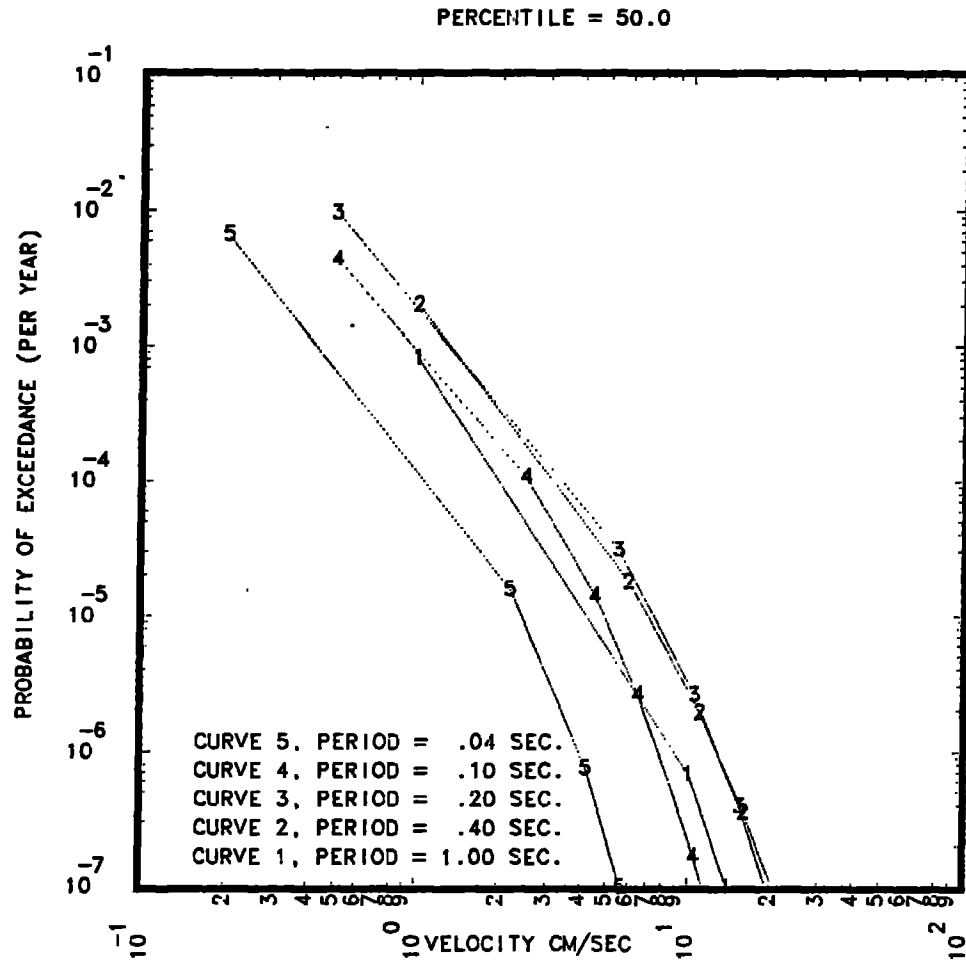
**Fig 79: 5, 15, 50, 85, and 95 percent constant percentile hazard curves for the Case 4 (only earthquakes with magnitudes between 4.0 and 5.0 contribute to the hazard) of the PGA for the Savannah River site when only four ground motion experts' inputs are used.**



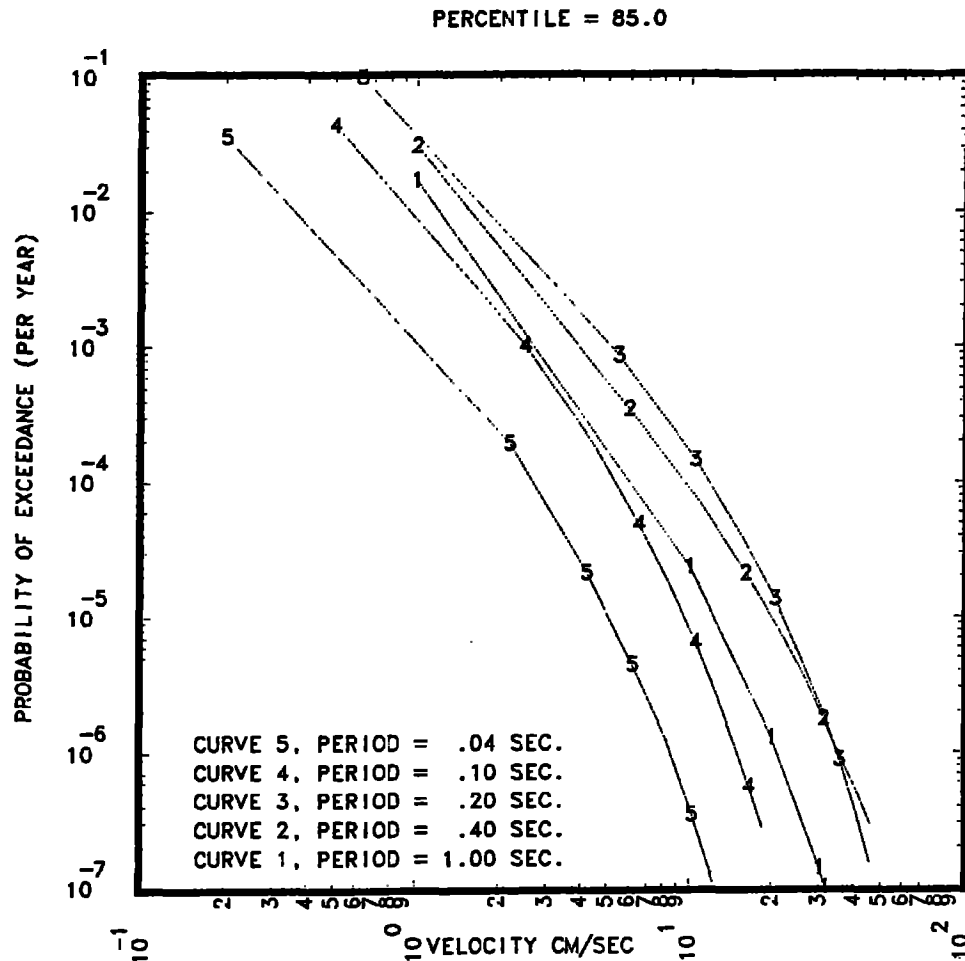
**Fig 80: 5 percent constant percentile hazard curves for the Case 4 (only earthquakes with magnitudes between 4.0 and 5.0 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site when only four ground motion experts' inputs are used.**



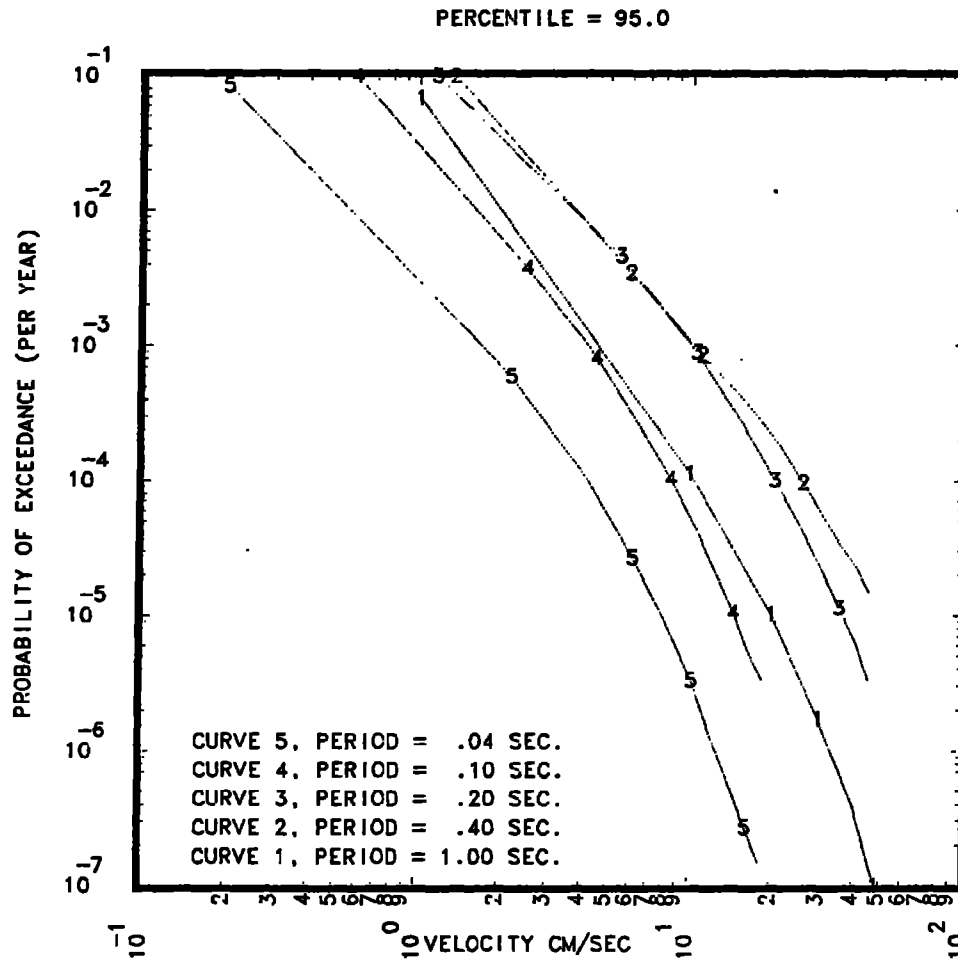
**Fig 81: 15 percent constant percentile hazard curves for the Case 4 (only earthquakes with magnitudes between 4.0 and 5.0 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site when only four ground motion experts' inputs are used.**



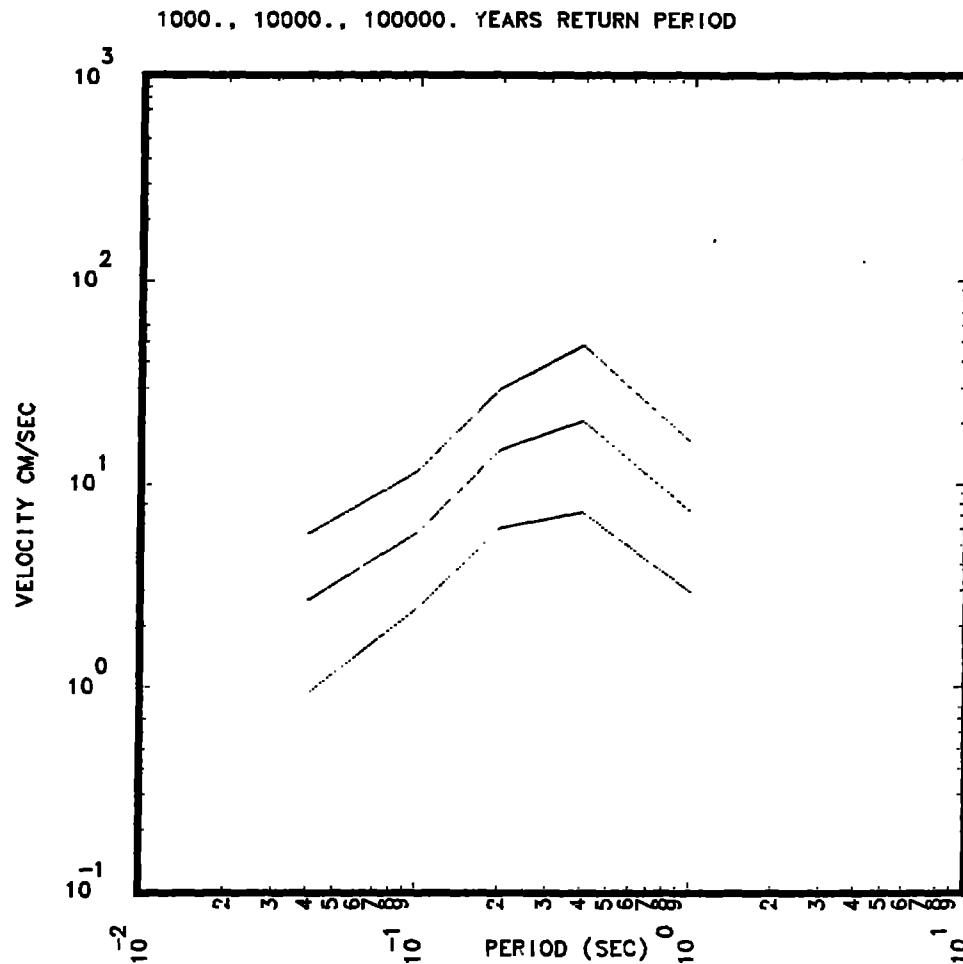
**Fig 82: 50 percent constant percentile hazard curves for the Case 4 (only earthquakes with magnitudes between 4.0 and 5.0 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site when only four ground motion experts' inputs are used.**



**Fig 83: 85 percent constant percentile hazard curves for the Case 4 (only earthquakes with magnitudes between 4.0 and 5.0 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site when only four ground motion experts' inputs are used.**

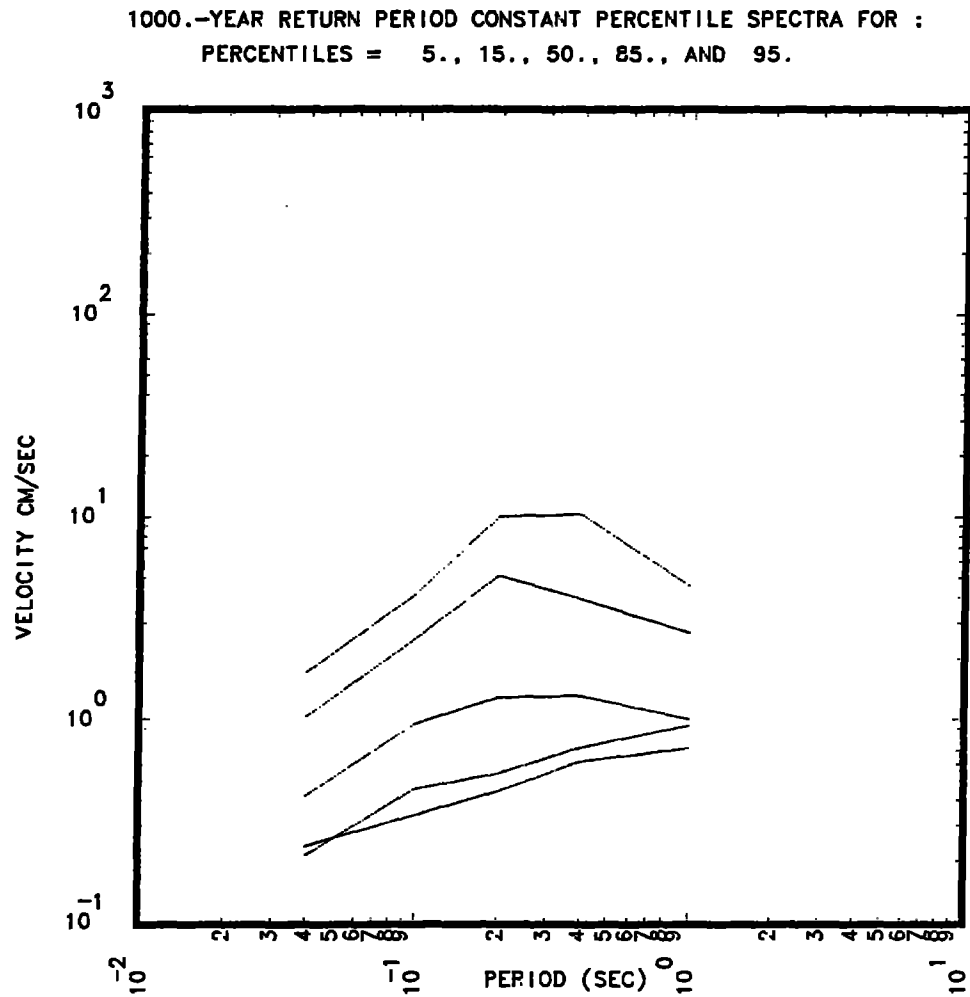


**Fig 84: 95 percent constant percentile hazard curves for the Case 4 (only earthquakes with magnitudes between 4.0 and 5.0 contribute to the hazard) of the PSRV at 5 frequencies for the Savannah River site when only four ground motion experts' inputs are used.**

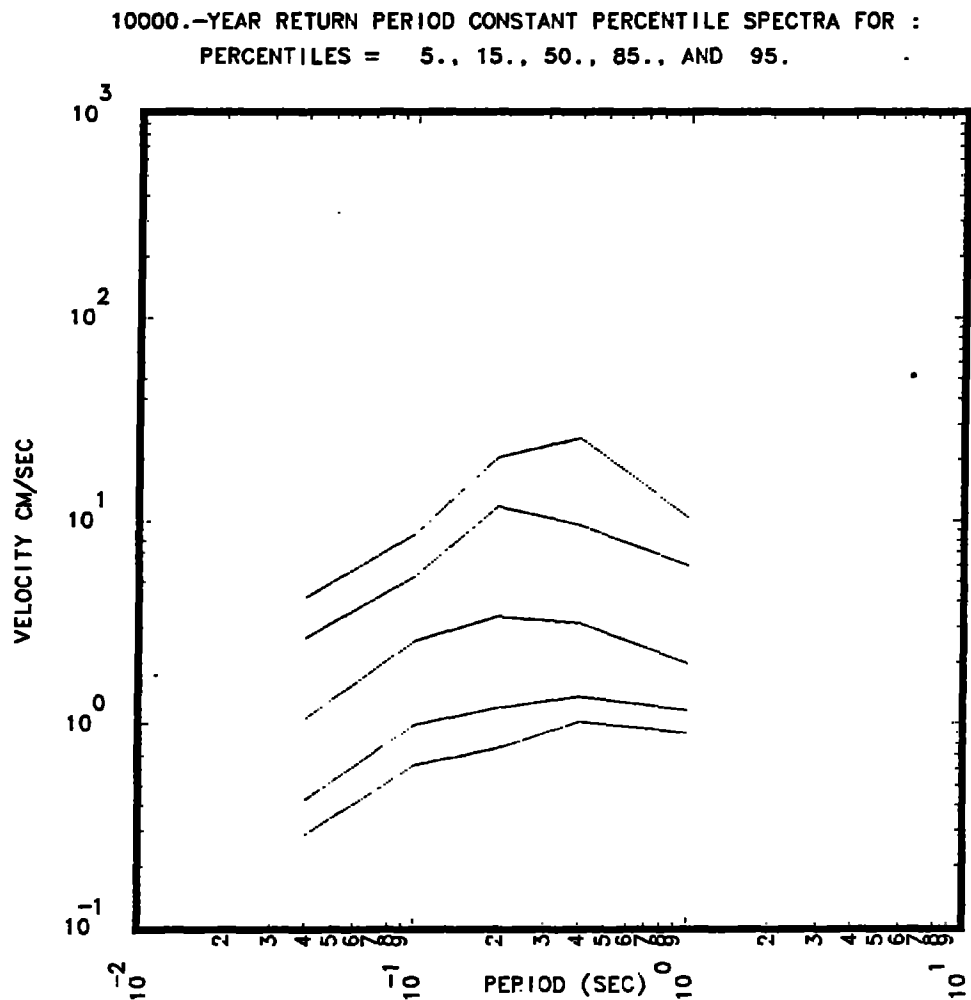


**Fig 85: Arithmetic average Uniform Hazard Spectra for three return periods for the Case 4 (only earthquakes with magnitudes between 4.0 and 5.0 contribute to the hazard) for the Savannah River site when only four ground motion experts' inputs are used.**

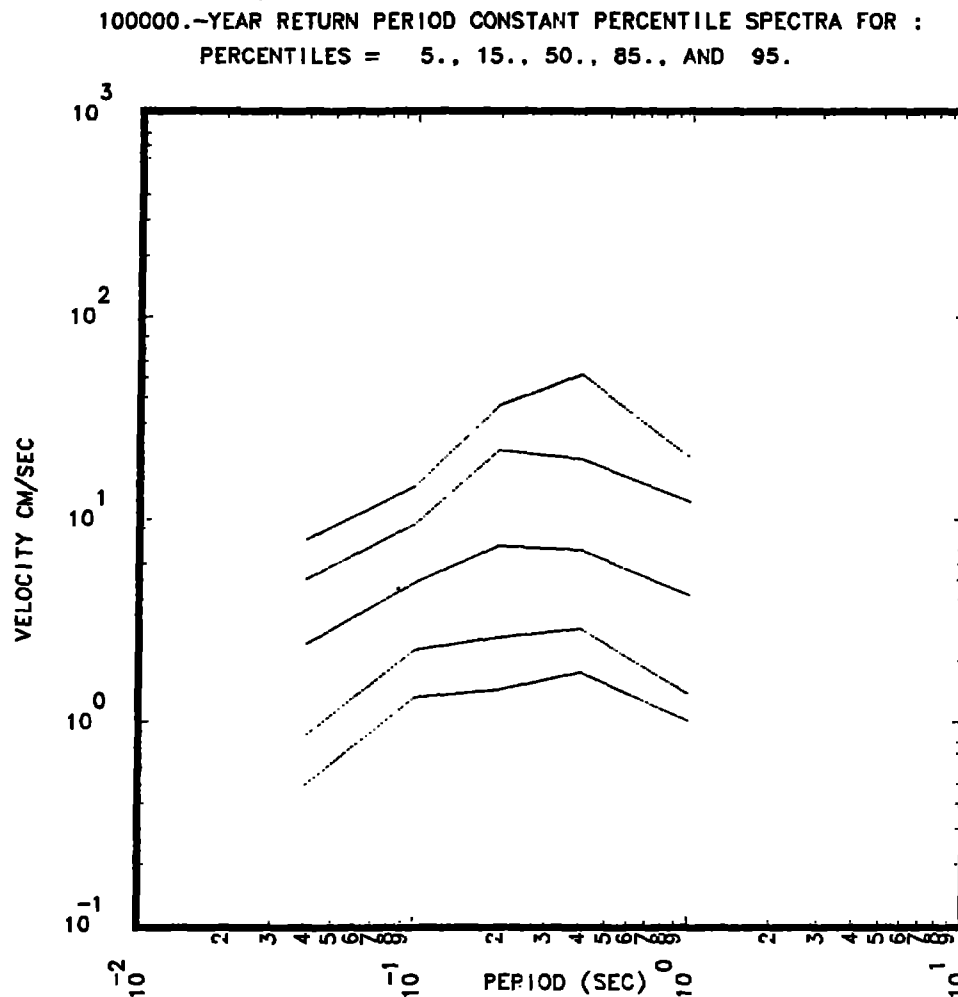




**Fig 86: 5, 15, 50, 85 and 95 percent constant percentile 1000 year return period Uniform Hazard Spectra for the Case 4 (only earthquakes with magnitudes between 4.0 and 5.0 contribute to the hazard) for the Savannah River site when only four ground motion experts' inputs are used.**



**Fig 87: 5, 15, 50, 85 and 95 percent constant percentile 10,000 year return period Uniform Hazard Spectra for the Case 4 (only earthquakes with magnitudes between 4.0 and 5.0 contribute to the hazard) for the Savannah River site when only four ground motion experts' inputs are used.**



**Fig 88: 5, 15, 50, 85 and 95 percent constant percentile 100,000 year return period Uniform Hazard Spectra for the Case 4 (only earthquakes with magnitudes between 4.0 and 5.0 contribute to the hazard) for the Savannah River site when only four ground motion experts' inputs are used.**

## **APPENDIX A. REFERENCES**

**Bernreuter D.L., J.B. Savy, R.W. Mensing, J.C. Chen and B.C. Davis "Seismic Hazard Characterization of the Eastern United States: Volumes 1 and 2". UCID-20412, April 1985.**

**Bernreuter D.L., J.B. Savy, R.W. Mensing and J.C. Chen, "Seismic Hazard Characterization of 69 Nuclear Plant Sites East of the Rocky Mountains: Volumes 1 through 8". NUREG/CR-5250, and UCID-21517, November 1988.**

## **APPENDIX B:**

**Seismic zonation maps for each of the eleven seismicity experts (S-Experts) who provided input to develop the data base used in the analysis of the Savannah River site.**

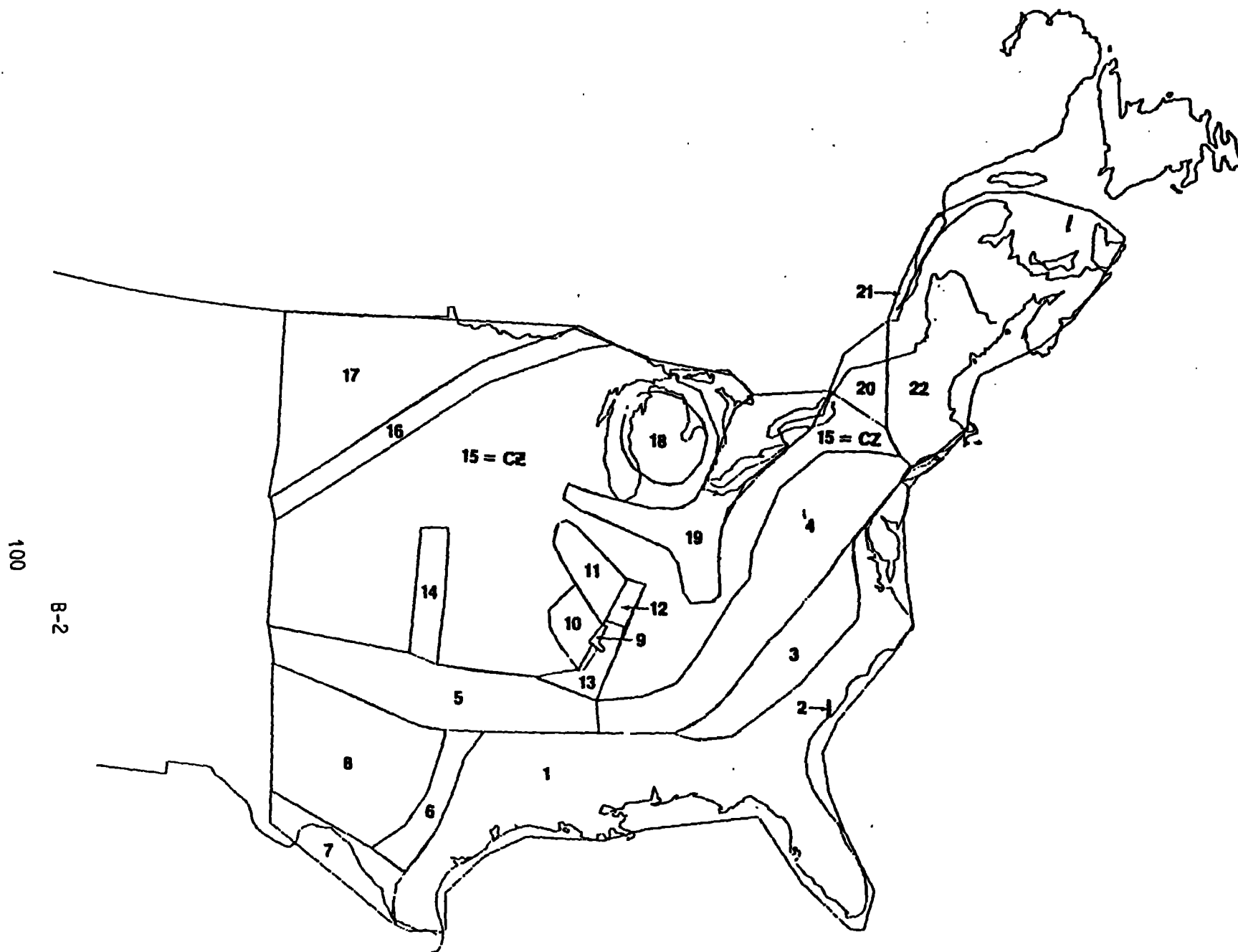


Figure B1.1 Seismic zonation base map for Expert 1.

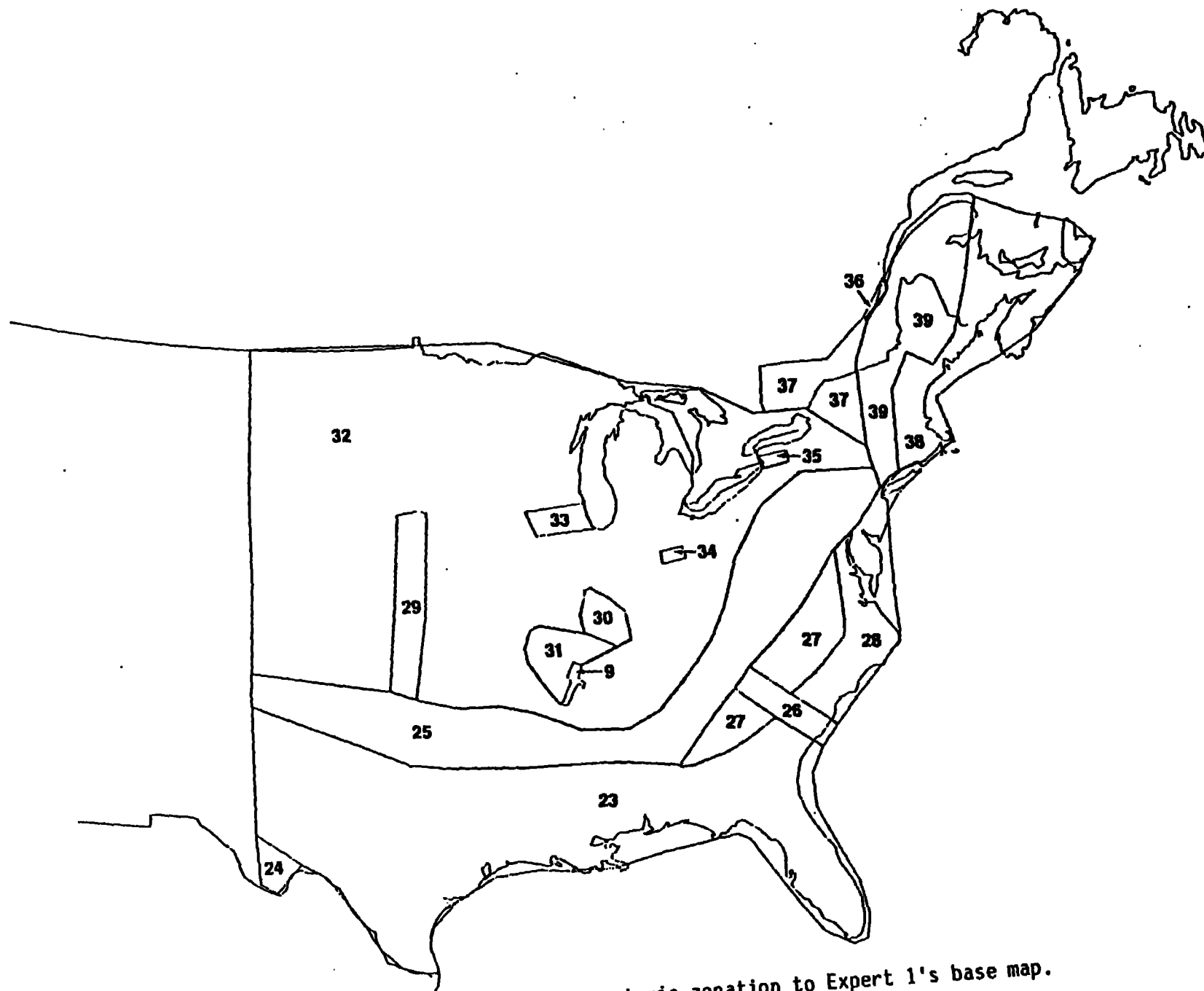


Figure B1.2 Map of alternative seismic zonation to Expert 1's base map.

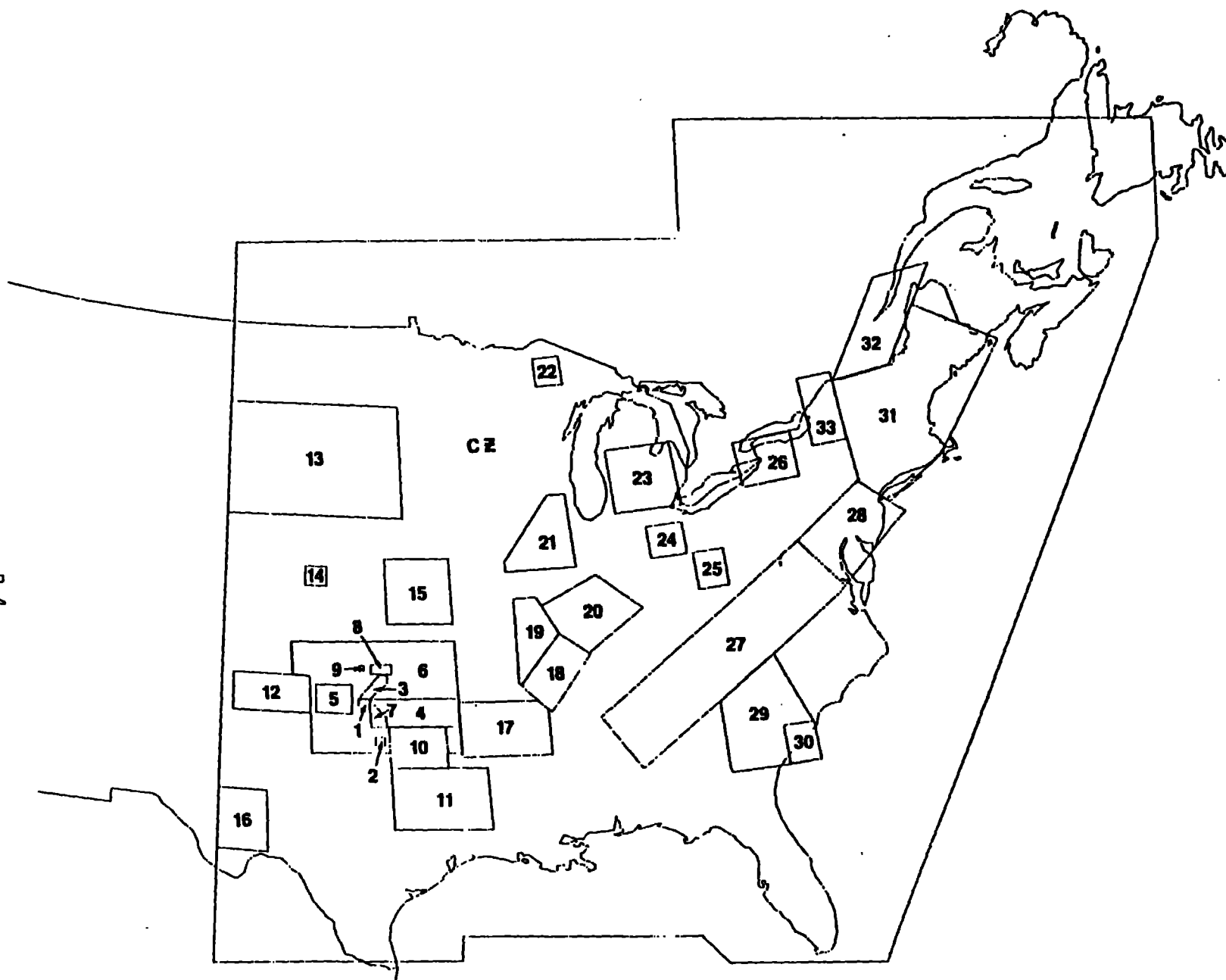


Figure B2.1 Seismic zonation base map for Expert 2.



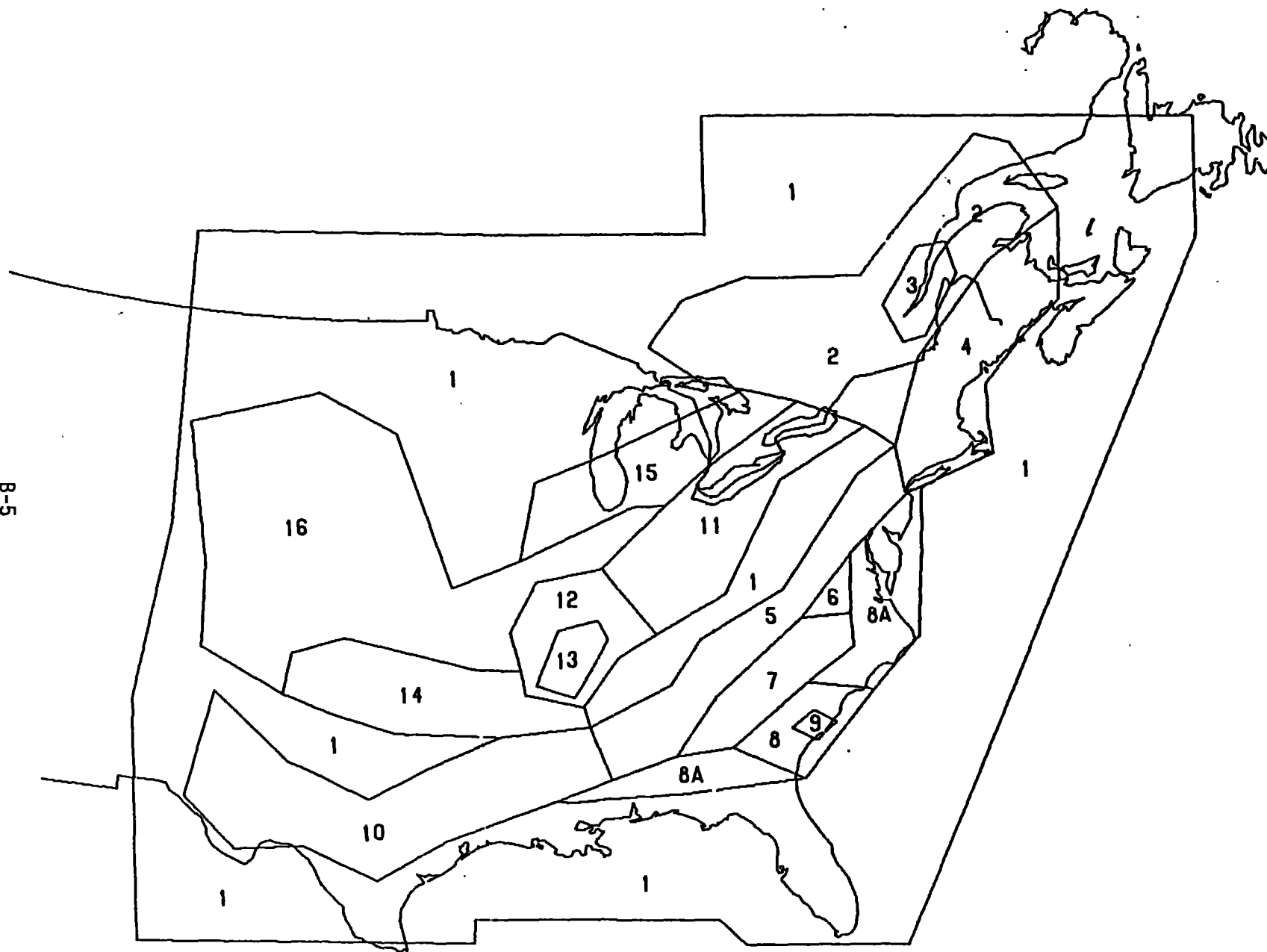


Figure B3.1 Seismic zonation base map for Expert 3.

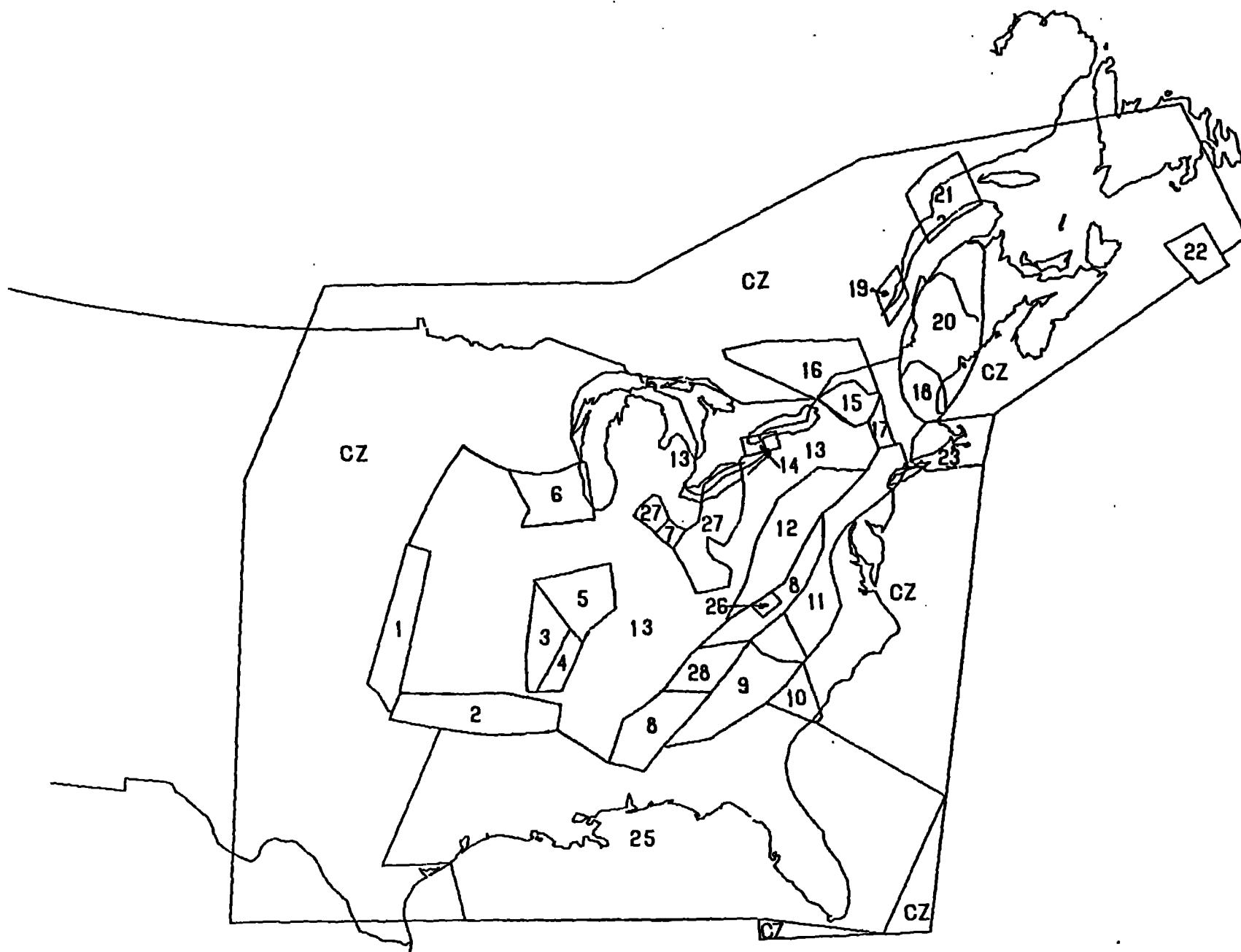


Figure B4.1 Seismic zonation base map for Expert 4.

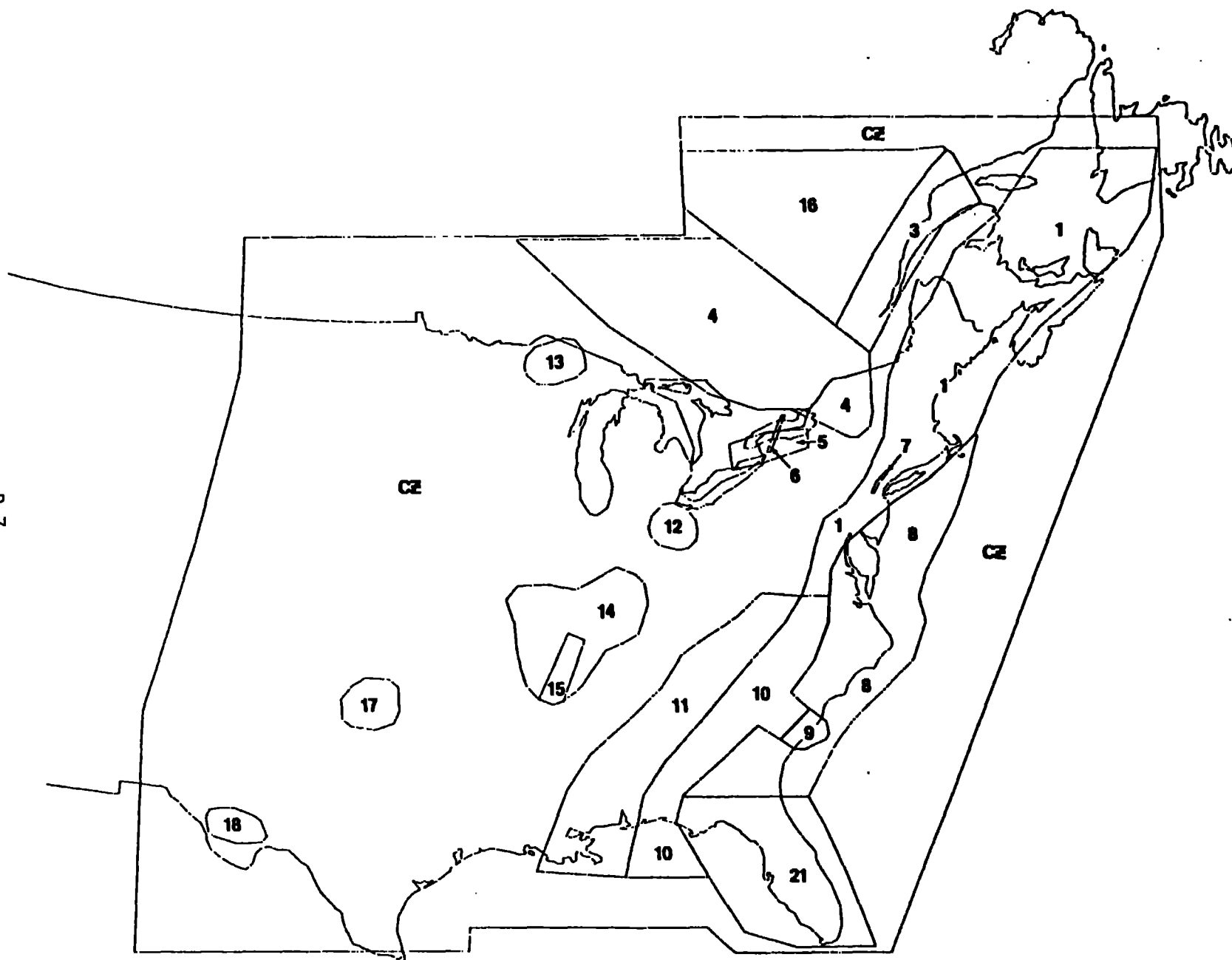


Figure B5.1 Seismic zonation base map for Expert 5

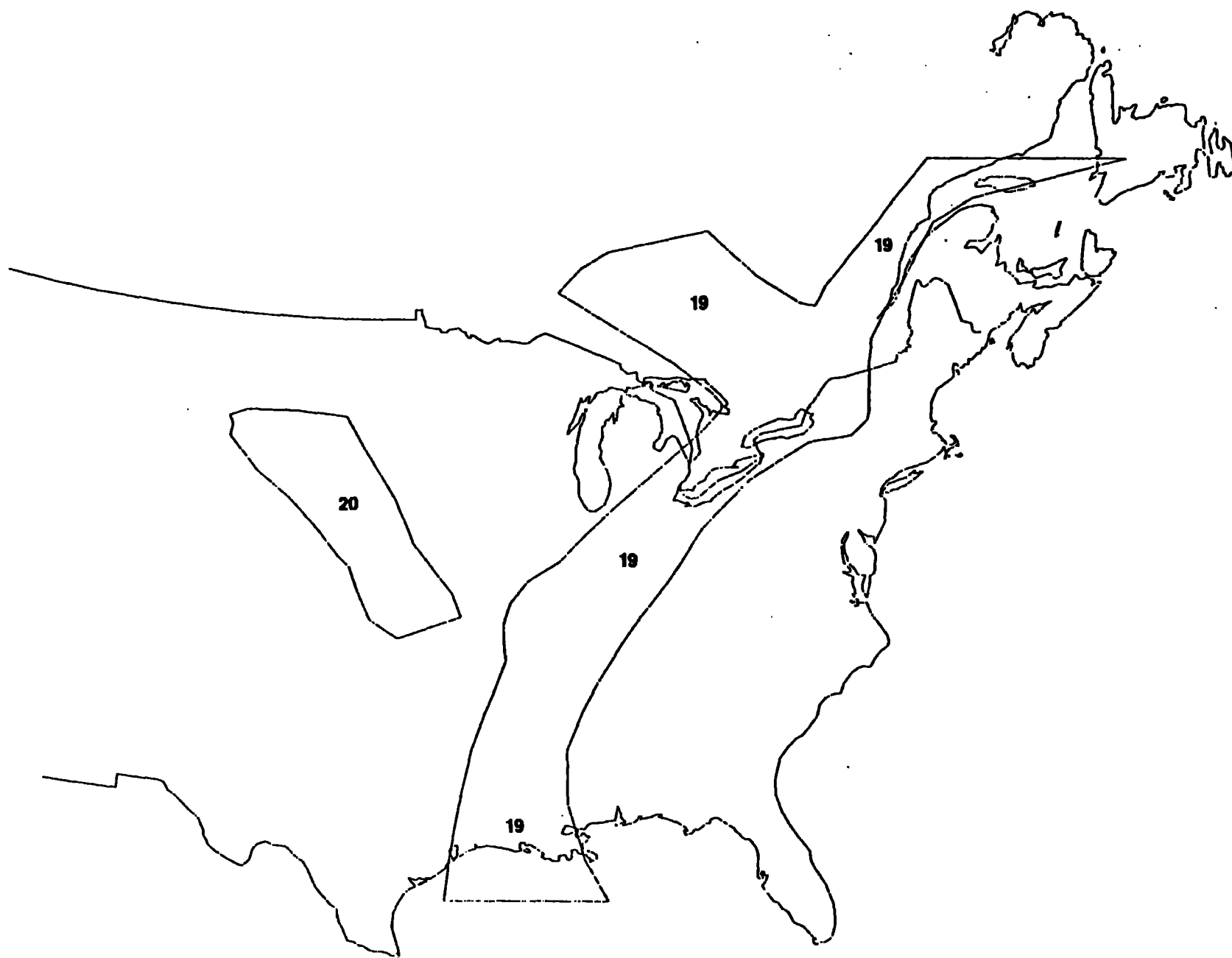


Figure B5.2 Map of alternative seismic zonation to Expert 5's base map.

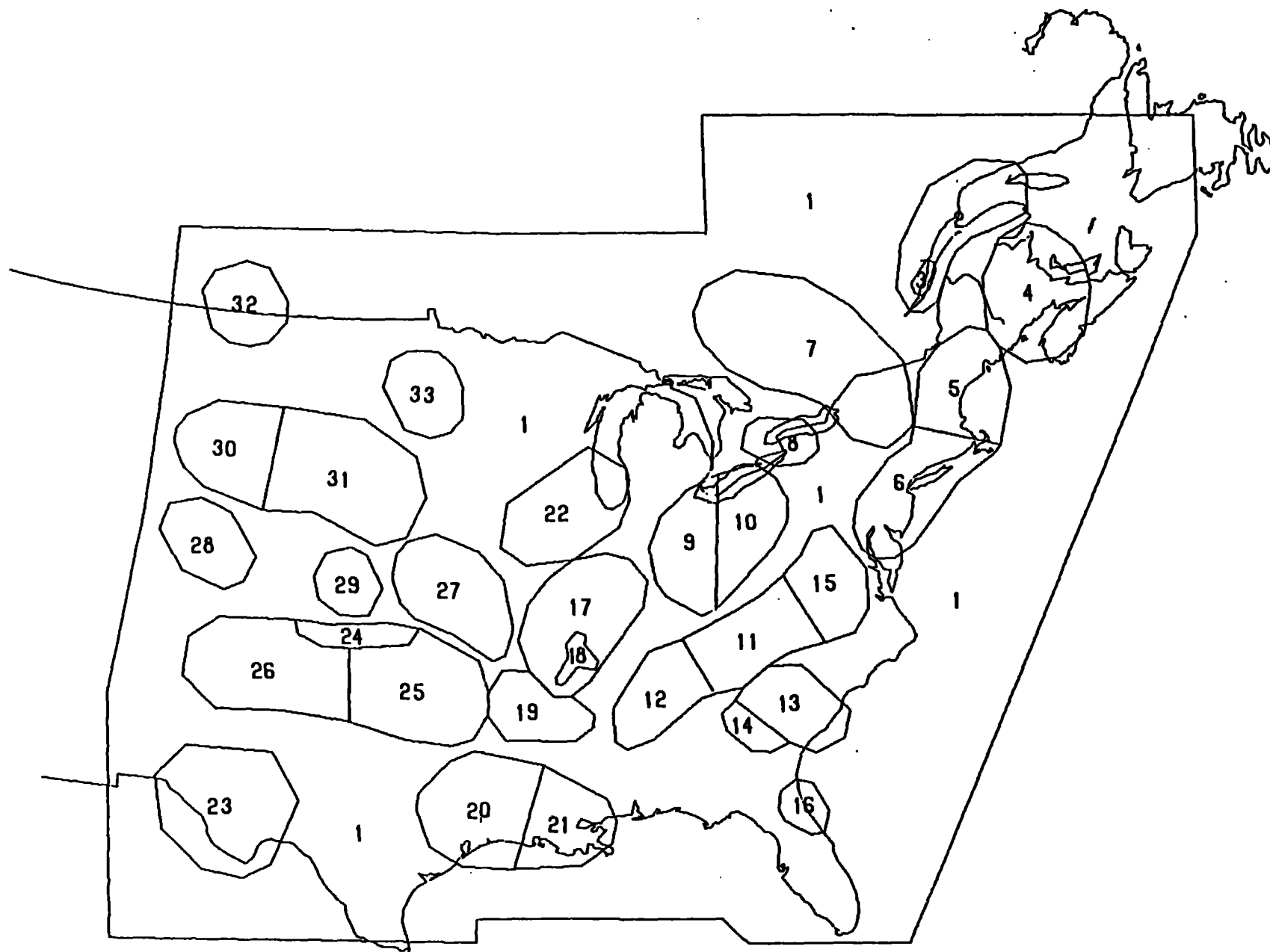


Figure B6.1 Seismic zonation base map for Expert 6

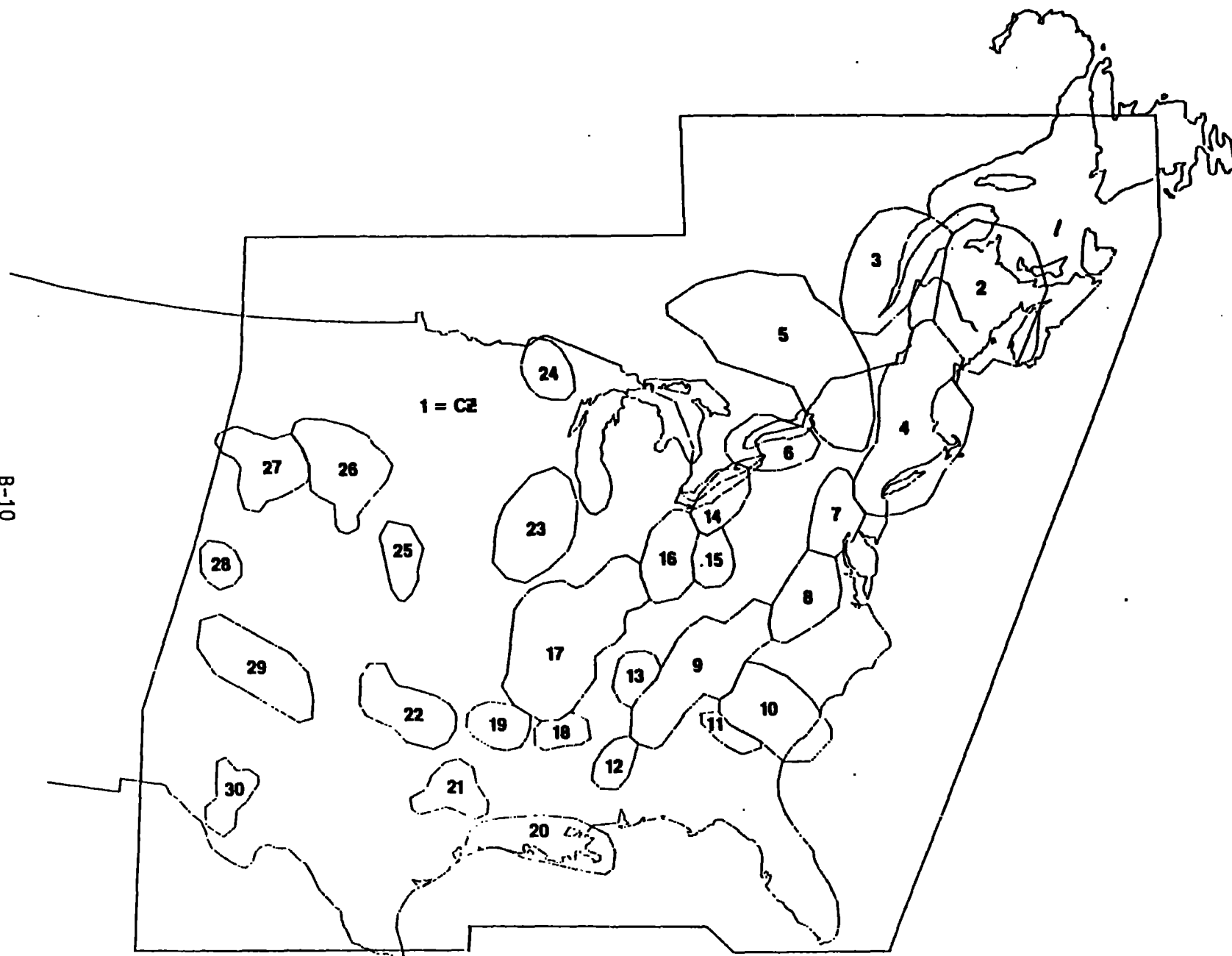


Figure B6.2 Seismic zonation map alternative 1 to Expert 6's base map.

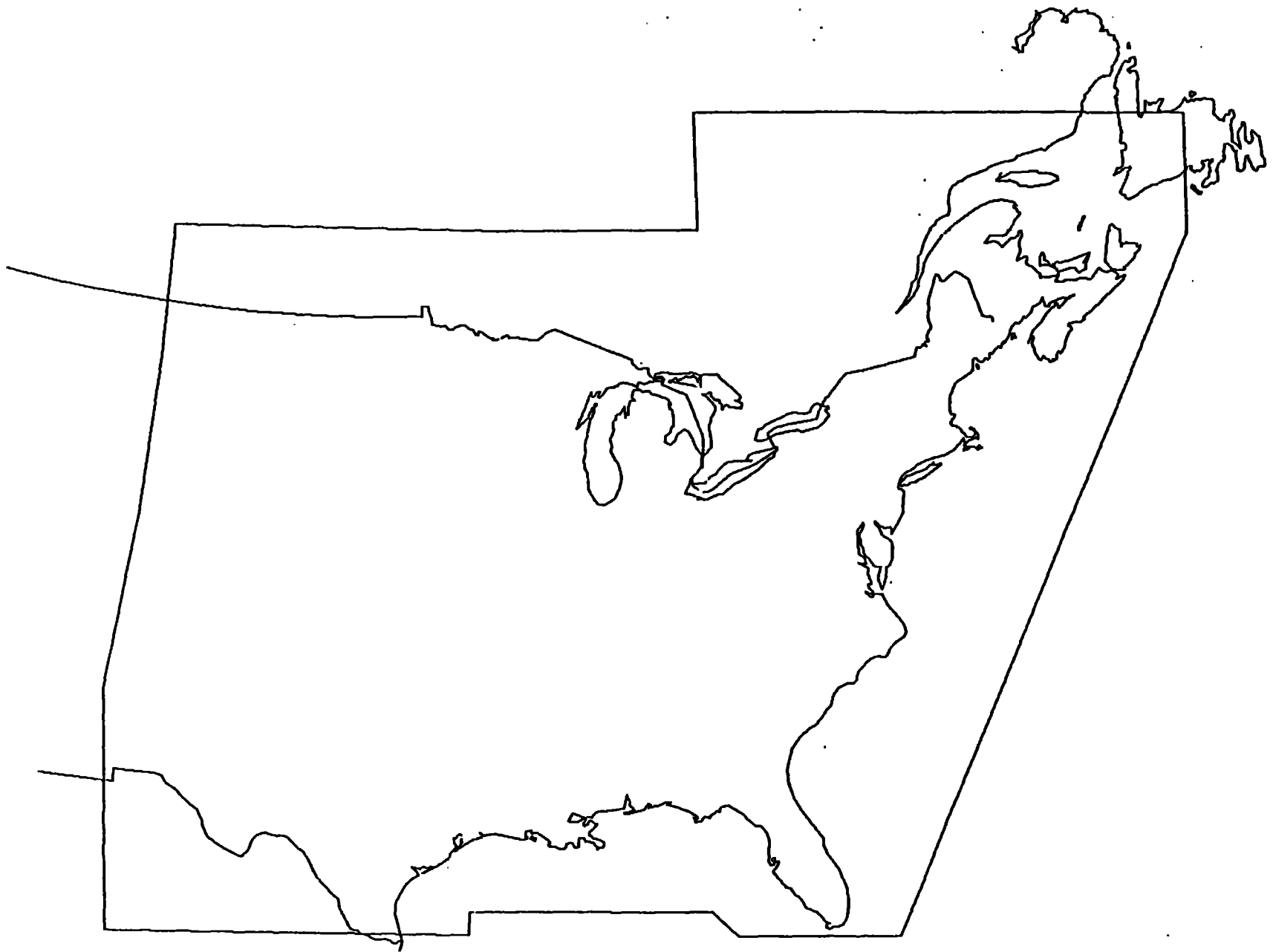


Figure B6.3 Seismic zonation map alternative 2 to Expert 6's base map.

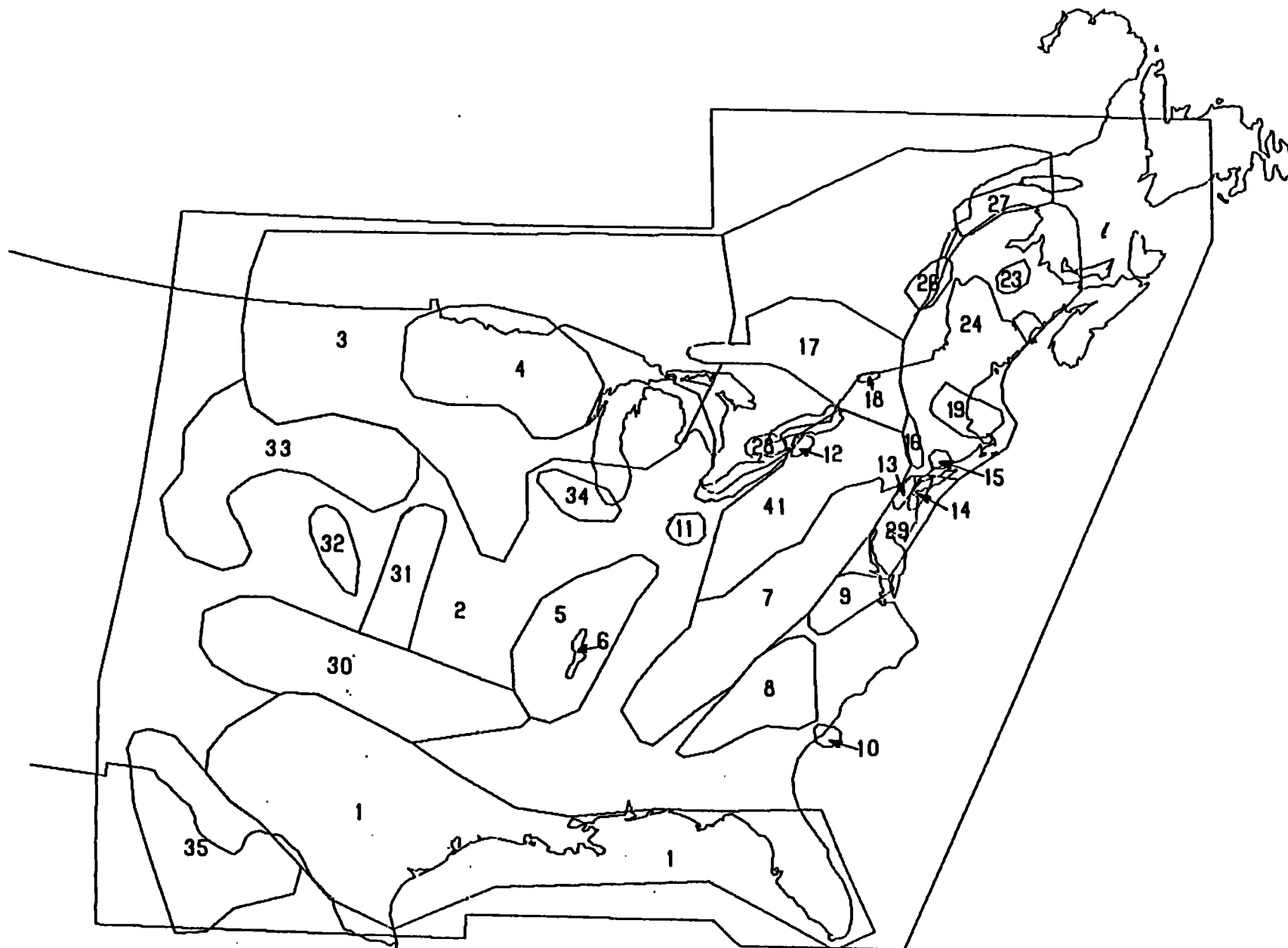


Figure 7.1 Seismic zonation base map for Expert 7.



B-13  
111

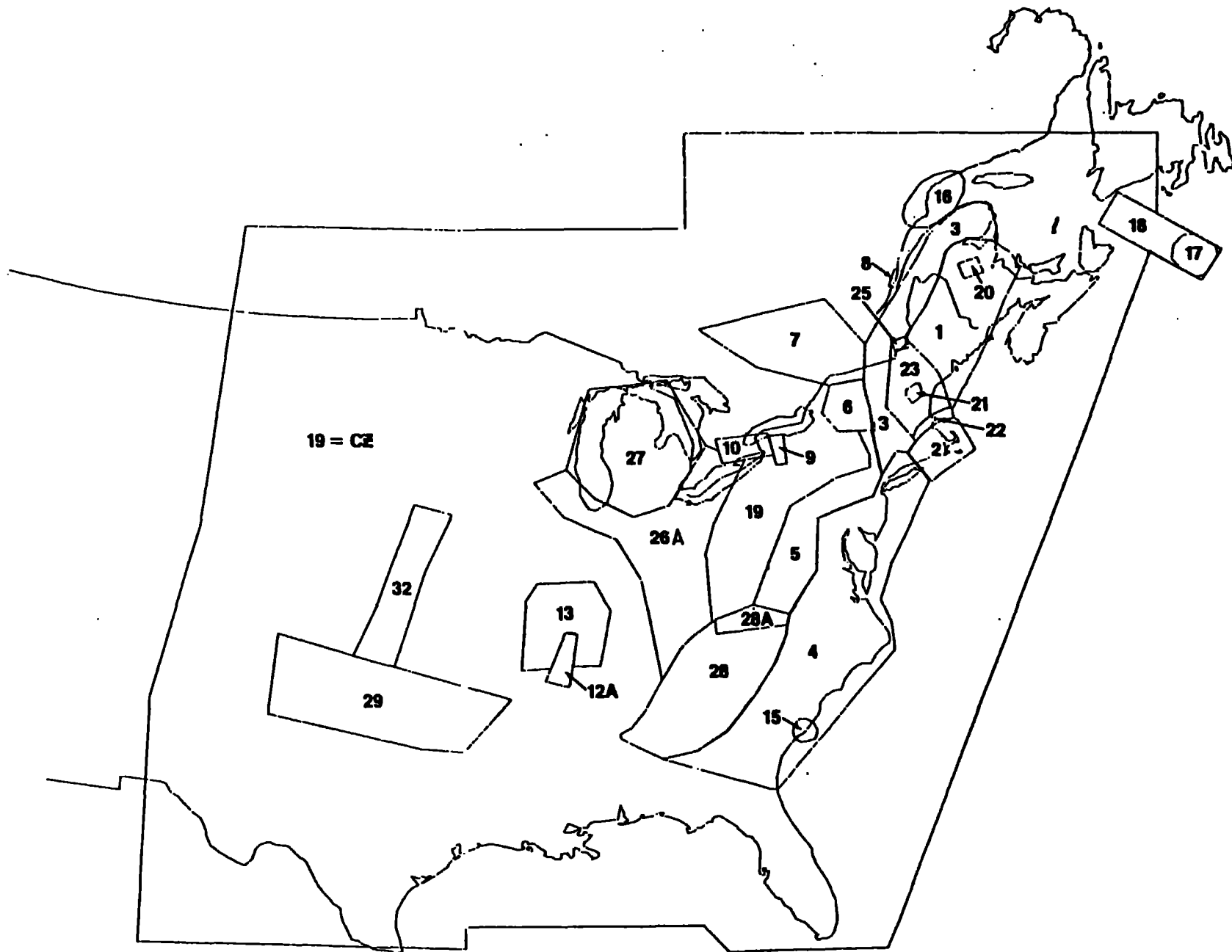


Figure B10.1 Seismic zonation base map for Expert 10.

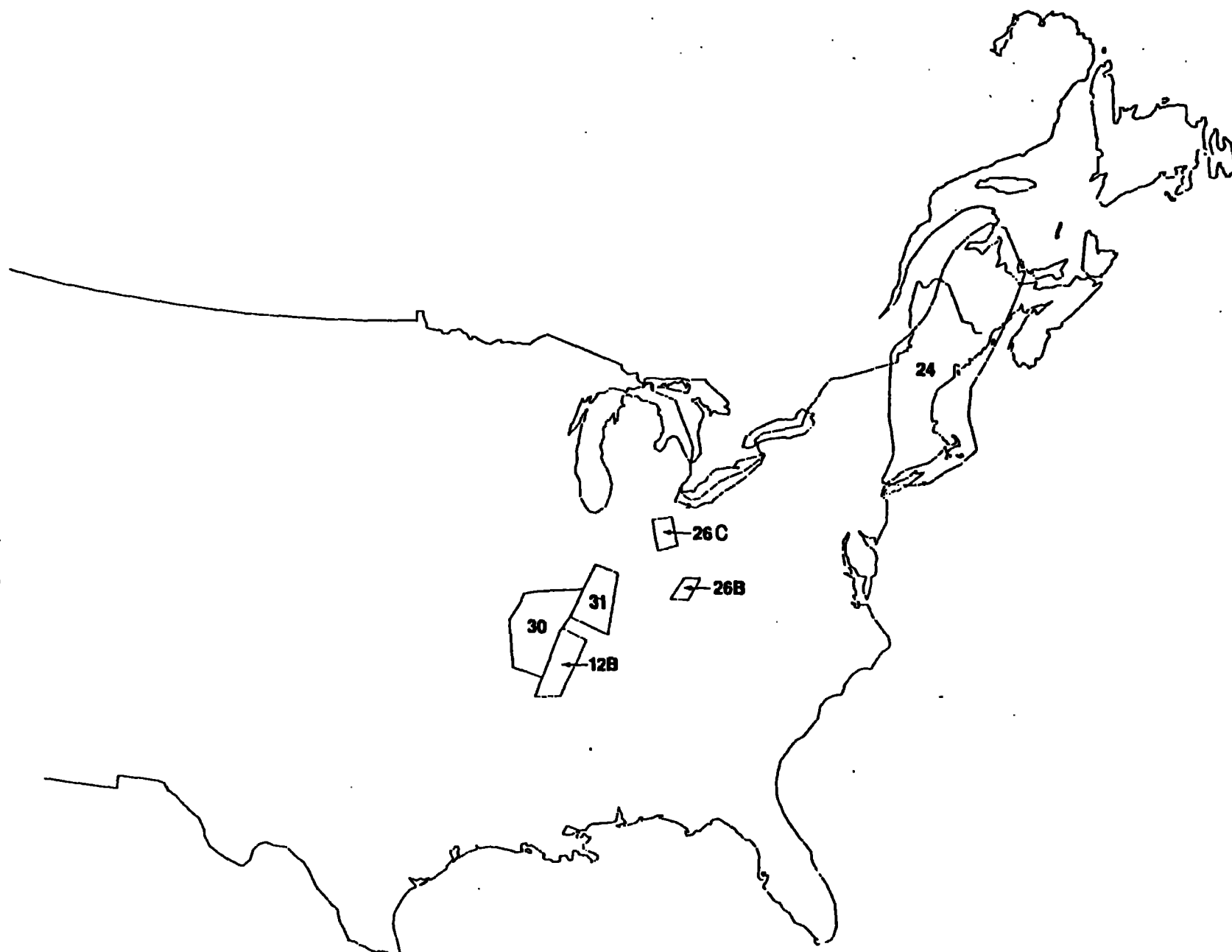


Figure B10.2 Map of alternative seismic zonation to Expert 10's base map.

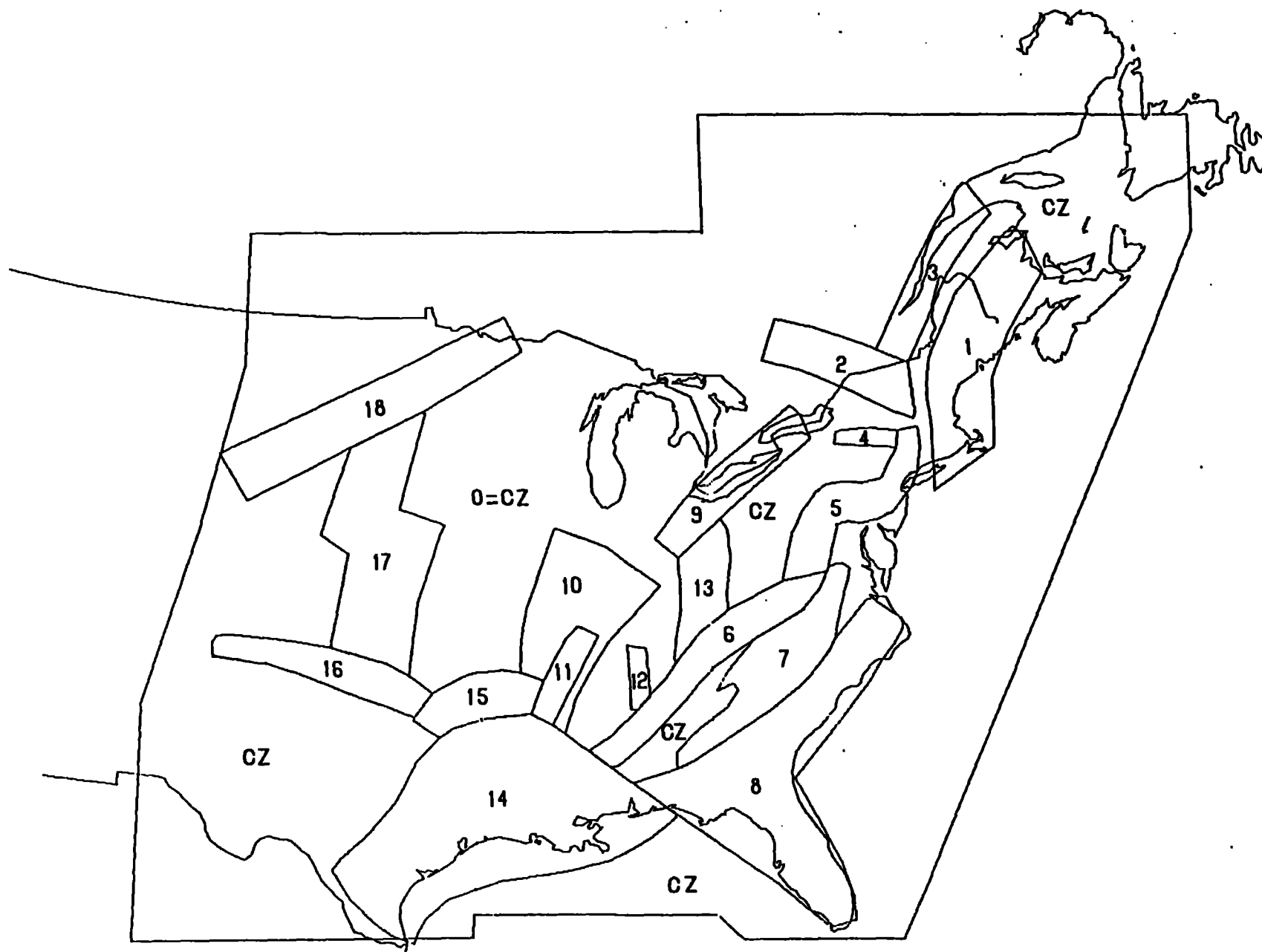


Figure B11.1 Seismic zonation base map for Expert 11.

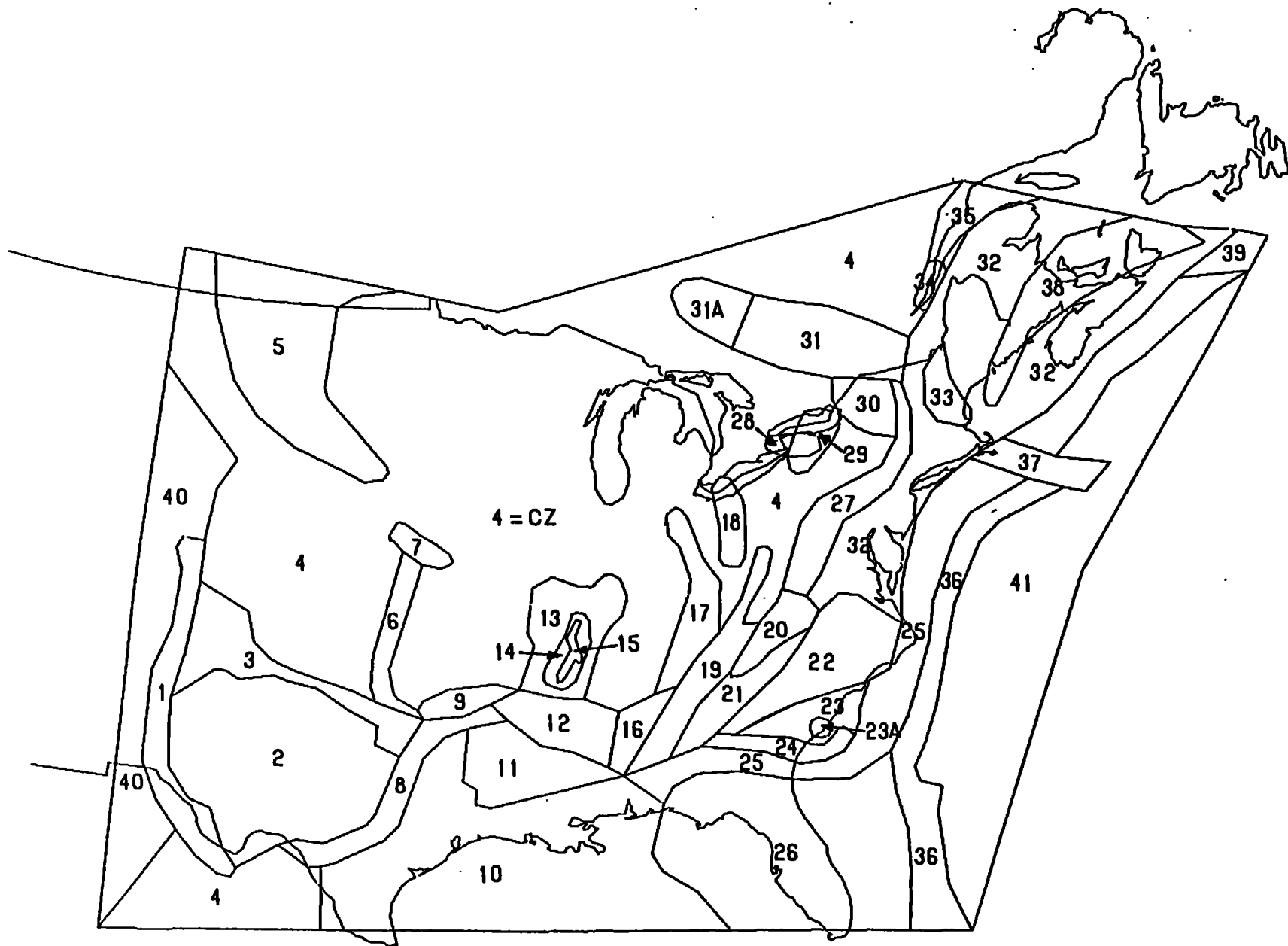


Figure B12.1 Seismic zonation base map for Expert 12.

B-17  
115

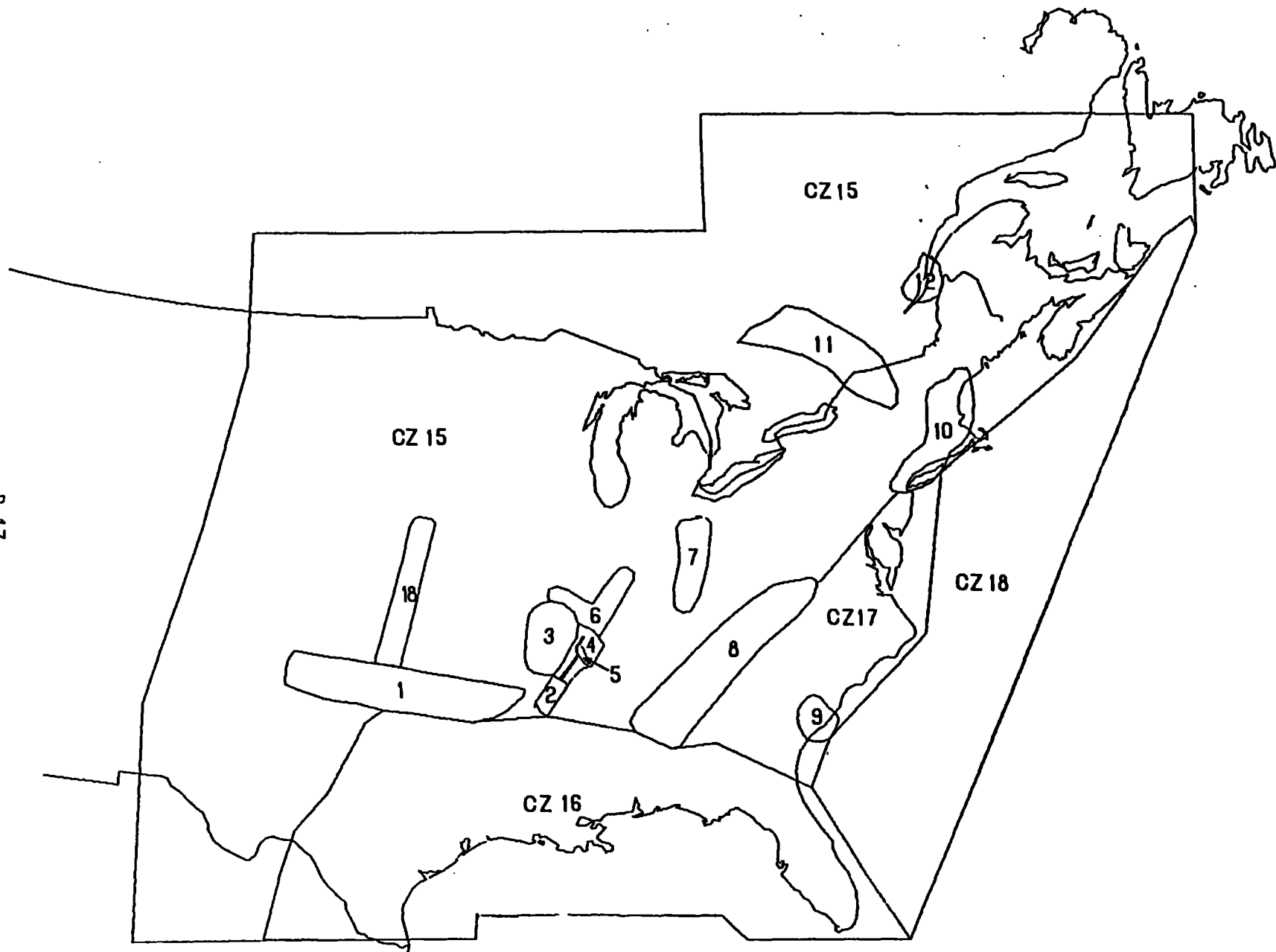


Figure B13.1 Seismic zonation base map for Expert 13.



Figure B13.2 Map of alternative seismic zonation to Expert 13's base map.

## **APPENDIX C**

**Seismic Hazard characterization of 69 Nuclear Plant Sites East of the Rocky Mountains.  
Volumes 1 to 8: Bernreuter, D.L., J.B. Savy, R.W. Mensing and J.C. Chen, Lawrence  
Livermore National Laboratory UCID-21517, November 1988, and NRC report  
NUREG/CR-5250. (to be published).**

